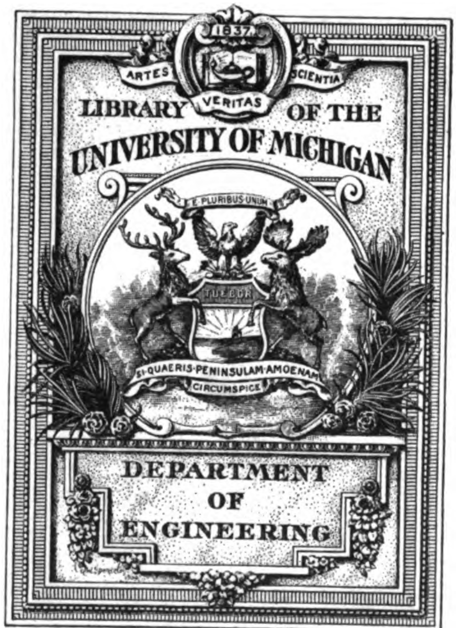
Grinding and lapping tools

Joseph Vincent Woodworth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GRINDING AND LAPPING

GRINDING AND LAPPING

TOOLS, PROCESSES AND FIXTURES

A Practical Treatise and Toolmakers' Reference Work upon Precision Grinding and Grinding Processes, the Preparation and Use of Abrasives, Lapping Processes and Methods, the Construction and Use of Laps, and the Design, Construction and Application of Fixtures for Grinding Accurate Repetition Parts of Steel and Iron; together with the Automatic Hardening and Tempering of Interchangeable Tool Steel Parts of Delicate Structure, and Percentages of Carbon, Necessary in Steels used for Various Tools and Parts, and which are Afterward Subjected to Grinding and Lapping Processes

BY JOSEPH V. WOODWORTH

Author of: "*Dies, Their Construction and Use*," "*Hardening, Tempering, Annealing and Forging of Steel*," "*American Toolmaking and Interchangeable Manufacturing*," "*Punches, Dies and Tools for Manufacturing in Presses*"

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PREFACE

In the pages following are shown engravings and half-tones of tools, machines, grinding fixtures, laps and lapping devices and arrangements, and combination fixtures for presenting duplicate work to grinding operations from the simplest to the most intricate in modern use; and we have endeavored to not only describe how to use them, but to describe and illustrate how to ***design and construct them*** as well, in a clear practical manner, so that all grades of metal-working mechanics may be able to understand thoroughly how to design, construct and use them for the economic production of the marvelous variety of machine parts and tools required to-day to perform the stupendous labor of our wonderful civilization.

Many of the tools and devices described and illustrated in this volume we designed and used ourselves; others were designed under our personal supervision; while others have been selected from published articles written for the technical press under our own name and various pen names. For many other descriptions and illustrations we are indebted to the kind courtesy of the editors of *American Machinist,* and *Machinery,* respectively, and here extend our thanks and sense of deep obligation to these journals for the privilege of using extracts and illustrations of articles which have appeared in their columns. For a large number of practical "kinks" and "points" we acknowledge our indebtedness to the numerous concerns with which we have been connected, and to the fellow workers with whom we have associated.

The sections on "Hardening and Tempering of Tool Steel Parts of Delicate Structure, which Require to be Ground and Lapped Afterwards," and "Carbon Percentages in Hardened and Ground Steel Tools and Parts," are so near akin to the general subject of this work, that they have been given a place so that the mechanic interested in grinding and lapping may become

thoroughly familiar with the practice necessary to create the necessary fundamental conditions in parts which are required to be hardened, ground and lapped to interchangeable dimensions.

We have endeavored to keep all obsolete matter out of this treatise, and to make every process, method, tool and device described represent the very highest that has been attained in the development and application of each type shown. With the object in view of giving to the present-day mechanic a volume treating of the design, construction and use of grinding and lapping, tools, fixtures and processes through which he may insure the increasing of the output and its efficiency, and at the same time lower the cost of production, we beg to submit this book for the approval of those for whom it was written.

JOSEPH V. WOODWORTH.

July, 1907.

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SECTION I

GRINDING; CONDITIONS, RULES, METHODS, PROCESSES, MACHINES AND ATTACHMENTS FOR ACCURATE GRINDING — USE AND PREPARATION OF ABRASIVES.

Grinding, Temperature and Water

It will be conceded by practical men, that the most important thing relating to the successful grinding of machine parts and articles of metal is the question of temperature, and it is possible that this is the reason why this method of removing material and finishing duplicate work is not more extensively used. Grinding without water gives very unsatisfactory and discouraging results. It is only within the past few years that makers of grinding machines have done much in the matter, as the revised conditions of machines of late design indicate.

An idea of the development that has taken place to date may be gained when it is understood that the first grinding machine built by those pioneers in the field — Messrs. Brown & Sharpe — had nothing but a tin of water below the wheel to catch the dust. A suds can over the wheel was an improvement, then a very small pump and tank were adopted. The largest machine we know of holds a hogshead of water, and delivers 50 gallons of water per minute at the grinding surface or point. Some condemn the plan of using water continuously, arguing, with reason, that upon using the water over and over again the lubricant becomes greasy and dirty, so much so in fact as to interfere with the wheel's efficiency. They condemn the use of soda for similar reasons, and advise a continuous supply from the public mains. The best results have been gotten from pure, clean water, and soda would never be used in the best shops were it not for fear of rusting the machines.

Grinding Cylindrical Work

In grinding any cylindrical piece of work, it will be found that its axis is constantly changing, and if heavier cuts are taken, it will appear to be, in fact is, out of truth to a greater or less extent, from the fact that at the grinding point the heat is greatest, and is constantly varying, and it will be found impossible to get a true job unless means are taken to equalize it. Hollow spindles and other tubes only aggravate the trouble, as there is less mass to absorb the heat generated. A good stream of water will always cure this, except in the case of tubes thin in section, when it is often found necessary to fill them and plug the ends. As an illustration of tube grinding the reader may imagine a tube with an oval hole, measuring 4 inches diameter outside, with a bore, say 3½ and 3¾ inches. If ground without filling with water, it will probably measure .0005 oval on the outside, the smaller place being at right angles to the smaller diameter of the bore. Therefore we will venture to assert that it is impossible to get round and true work without water. Added to that, the production is as three or four to one against dry machine grinding of parts.

Straightening Hardened Work Before Grinding

Straightening hardened work has generally been found a waste of time. By heating the work to a temperature that is not hot enough to soften it one may be able so to true the job that it will clean up to the finished dimensions, but it will almost certainly go back, although it may be weeks before this becomes evident. We have seen cases that would illustrate this in work from firms whose reputation is above question. It seems to be the best thing to soften, straighten, and then reharden. In soft work one has the same trouble, only it is in a reduced degree, though the distortion seems to depend much upon the previous machining. It may seem almost incredible, but it is a fact, that work that comes from the bar lathe frequently gives more trouble than work done on centers. It has been advanced that in the bar lathe — heavy reductions being the rule — there is not the same apparent necessity to true the stock before turning, and that on grinding away the hard skin left by the steadies, the previous distortion develops. If this is the reason it would seem

to show that bars should be straight before commmencing to turn. As we have mentioned before, we do not really know the reason, but think that it is a matter for discussion and experiment. A shaft that has sprung during turning and then been straightened will resume its bent form again more or less after a slight reduction has been made. It is a good plan to spring it over the opposite way first and then straighten it. It will be found that in the majority of cases it will remain straight if this has been done.

Indispensable Condition for Good Grinding

It must not be imagined for a moment that grinding a job is a guarantee of its quality. As a rule, a sample of ground work looks very nice with its clean, sharp corners and uniformity of finish. It looks just as pretty when .001 below size. One can spoil work on a grinding machine as on any other machine, by want of thought, which is the usual reason for scrap, and the man at the wheel is sometimes a careless workman.

The expression is often heard: "Oh, it's all right; it's been ground," which is paying the grinder a compliment he does not always deserve. We have heard it said: "Oh, it's good enough; it's got to be ground." Now it is not our object to preach a sermon, and commence by stating that carelessness in one thing leads to carelessness in others, but we will state that the lathe hand can ease the grinder operator in many ways that will be quite obvious to him.

The fact cannot be emphasized too strongly that good centers are indispensable.

In this matter of good centers it may be added that very many shops need education, and probably there are far more of them than of those who do not. It ought to be obvious that it is useless to provide accuracy in the spindle bearings and movements of a grinder or lathe and then provide centers for the machine and for the work which do not fit each other at all, and which cannot possibly maintain the same axis of rotation from the beginning to the end of a job as centers should.

Surface Grinding

In the following matter embodying the results of experience in surface grinding, we do not claim to point out the way to

obtain absolute accuracy, but are confident that the hints here given will be of use to many in the effort to reduce the error limit. Best results are to be obtained only by the exercise of good judgment on the part of the operator, as a little common sense is one of the qualifications for the work.

It is believed that much of the trouble experienced with grinding machines is due to the use of unsuitable abrasive wheels and to a desire to force the wheel beyond its limit. It is also well to bear in mind that the size of the wheel bears an important relation to the successful removal of stock, and that heating is not necessarily harmful to work if it is distributed evenly.

In doing precision surface grinding every operator has doubtless run up against the following difficulties: In grinding wrought metal (especially machinery steel), difficulty is often experienced by the work showing a convex surface even after a very light cut has been taken. Sometimes when using the same wheel on the same work, the latter will show a concave surface. A chattery surface is a very common trouble experienced. In starting a light finish cut it sometimes happens that a cut .001 inch deep will run out after a few strokes.

Taking up, first, the case of the convex surface, the operator will be apt to jump at the conclusion that the trouble is due to an absence of water on the work or that a strain had been relieved in the work by the cut. If the emery wheel be carefully examined, it will be found, probably, that its surface is more or less filled up with particles which have in a measure transformed the wheel into a friction disk, the particles of metal rubbing down the surface of the work forming a crust with an effect like peening to stretch the surface and cause it to become convex.

Now, in the second case, where the reverse happens, there is a seeming paradox. The explanation is that the wheel has been forced to cut beyond its limit and that a good deal of heat has been generated, causing sudden expansion of the work immediately under the wheel where it is laboring the hardest. This, of course, causes the wheel to cut deeper at this point. As the wheel has gained added momentum at the starting end of the work, it starts on at each end without much heat. When it is well into the midst of its cut, there is considerable heat, the work undergoes a temporary expansion, and the wheel cuts deeper.

The remedy in the first case is to use a softer wheel, taking

light cuts with coarse feeds. In the second case, do not try to force the grinding wheel beyond its limit; or if you must use the grinder as a roughing-out machine, you must employ the freest cutting wheel obtainable.

Chattery work is due to several causes, any one of which will cause trouble. First, a poor cutting wheel; second, an over-worked wheel, and third, a machine lacking rigidity. Also slack in the spindle will tend to encourage vibration. An entirely smooth surface is difficult to obtain with grinding machines or indeed with any machine, but a close approximation can be obtained by observing the following rules.

Rules for Accurate Surface Grinding

Take up all possible slack in the spindle. True the wheel frequently and run light cuts. The wheel must be given time to remove the metal, and the smaller the wheel the more time required.

Improved results are obtained generally by reducing the width of the wheel face. It is the best practice to bevel both sides about 30 degrees, leaving about ¼ inch more or less for the cutting face. The more pressure required to hold the wheel to its work, the more trouble with chatter; hence, use wheels that will cut freely. Never let the wheel wear much tapering on the face. To prevent this, feed the plates or wheel backward as well as forward. The result of this will be that the face of the wheel will assume gradually a rounded contour. This is better than to have it wear tapering or rounding on one side only and wedge on to the cut.

A special truing machine should be added to the equipment of a surface grinder and should be arranged to be held on the platen directly under the wheel, and fed under so that the wheel face may be made parallel to the work face. It is a good plan to true the wheel just before taking the finish cut on very fine work.

We will suppose that the operator has mastered all the above details, has his wheel trued off, and wishes to grind off a finish cut of a fraction of a thousandth of an inch in depth. He sets the machine in motion and everything starts off well for a half-dozen strokes, when the cut suddenly runs out. We wonder if

it ever occurred to this operator that oil must necessarily occupy some space and that a spindle must necessarily have oil between it and its box; also, if a spindle be stopped, that this film of oil must gush out somewhere and the spindle settle down somewhat on account of its own weight? This is the explanation of the mystery. The moment the spindle is stopped it commences to settle and in its lowest position the wheel should not be adjusted to the work. When the spindle starts up, it gradually rises on the film of oil again. The remedy for the above trouble is simply to let the machine run for a minute before adjusting for the finish cut.

Hints for Surface Grinder Operators

The result of the foregoing is embodied in the following hints for surface grinder operators:

First, make sure that the machine is lubricated and that it runs freely in every part, especially in the emery wheel adjustment.

Don't expect to adjust the wheel to fractions of thousandths of an inch without rapping on the index handle.

Select an emery wheel of as large a diameter as possible and one that is coarse and free cutting.

On tough, tenacious metals like wrought iron, machinery steel or brass, the best results in respect to finish are obtained by the use of fine soft wheels taking very light cuts with coarse feeds. The wheel must wear away somewhat to insure good results.

A small wheel must not be expected to do the work of a large wheel in the same time. Finer feeds and slower platen speeds should be employed for small wheels.

A grain of emery has the capacity for performing a certain definite amount of cutting before disintegration, hence two grains of emery in a wheel will perform double the work of one, and the latter will change its diameter twice as fast and produce work of less accuracy.

Speeding up an emery wheel helps to keep it from wearing away, but the advantage to be derived is limited by practical considerations.

A glazed or a filled wheel can sometimes be remedied by slowing it down and thus forcing it to wear away.

Avoid generation of heat as far as possible, although heat does not necessarily cause the work to spring. All grinding wheels heat more or less, and little trouble will be caused by this if the heat is distributed evenly throughout the work. It is intense heat at one point that causes the trouble.

Where much heat is likely to be generated, employ coarse feeds and very light cuts and thus distribute the heat quickly.

A cut .001 inch deep is a large cut for finishing.

A cut .0001 inch deep is appreciable and looks larger, judging by the sparks.

On precision work, always let the machine run idle for a minute before adjusting the wheel for the cut.

The down feed must work easily to obtain best results.

Keep all wear of spindle taken up.

Do not oil the grinding spindle in the midst of a cut. It will make a jog in the work.

Coarse wheels of proper texture cut smoothly.

Development in Uses for Emery Wheels

In machine shops the development of uses for emery wheels has been remarkable, and there is to-day an immense amount of work done with the emery wheel that a few years ago it was not considered practicable to handle in this way. In one shop we have in mind a recent test was made where a shaft which had $\frac{1}{64}$ inch all around to be removed was placed in an emery grinding machine. At the same time a duplicate of this shaft was placed in a lathe. The grinding machine finished the shaft in a little over 37 minutes, leaving it in better condition than the lathe, in which it took two hours and eight minutes to finish the work. Another test on an emery surface grinder with a wheel 12 inches diameter by 2-inch face, medium hard and very coarse, on cast iron, showed excellent results with a cut $\frac{1}{4}$ inch deep, $\frac{1}{8}$ inch cross feed, and 35 feet table feed per minute. This seems almost incredible, but is nevertheless true.

The most recent development in design of emery grinding machines is a surface grinder having a circular table, similar to a boring mill, and a wheel about 16 x 2 inches arranged to be automatically fed in to the center and out to the edge. The machine is so substantially built for heavy cuts and accurate

work that it is well adapted to the grinding of valves of steam pumps, air compressors, etc. This will tend to show that the grinding machine manufacturers are determined to invade all branches of machine shop practice.

There is another machine which is being used for grinding very heavy shafts, that is intended not only to finish the work but, where shafts can be cast or forged reasonably close, will remove the stock and also finish the piece without its having to be put in a lathe for the roughing cut.

In obtaining results in emery grinding, several things must be considered: 1. The required condition of the work when finished, whether it is to be polished when taken from the machine, or polished by buffing afterwards. In the latter case the number of the emery that is used in the buffing must be considered. It is to be considered also whether the material to be ground is tempered or not, before or after grinding. 2. How much stock is to be removed. 3. What is the nature of the material to be ground — cast steel, machinery steel, chilled iron, brass, malleable iron; and is it hard or soft? 4. Are the pieces light or heavy? How much metal is there in the part to be ground to absorb the heat? All these things must be taken into consideration in order to ascertain the proper method of performing the work and the grain and grade of wheel to do it correctly.

In regard to grain and grade of wheels, it may be stated that the best results are always obtained by using as coarse and hard a wheel as possible, as a coarse, hard wheel will not fill with metal so easily, and will not scratch so deeply.

In a recent test made where the steel was hard and to be tempered and very highly polished, much finer work was produced on a wheel 6 x 8 inches, made of No. 16 hard emery, than on one of No. 46 material, and softer. The latter made deeper scratches that could not be polished out, and the former left the work in excellent condition. When polished, its surface was in as perfect condition as after having been ground on a grindstone.

Better results will also be obtained by using wheels of large diameter; the larger the diameter of the wheel the better the results. We have known individuals in shops and foundries to complain that they were not able to get any results from grinding their work, and upon examining the conditions found that they had a small machine, carrying a 14- or 16-inch wheel of about

2-inch face, the machine being merely bolted to the floor with considerable vibration in it. These same people were induced to install a substantial machine and use a 24-inch by 3- or 4-inch wheel, running it at 1000 revolutions per minute, having the machine on a concrete foundation, and they were astonished at the difference in the results.

For heavy steel castings, chilled iron or hard castings, excellent results may be obtained by the use of a swing frame grinding machine with an elbow joint, operated with a man at each side of the wheel. A gate on a heavy steel casting 5½ inches in diameter, ⅝-inch high, has been ground entirely away in 13½ minutes with one of these swing grinding machines.

Another point of considerable importance is the speed at which the emery wheel runs. One should be just as particular in getting the proper speed at which to run an emery wheel as in procuring information to start a planer or a lathe or any other machine that he is setting up in the shop. Where one buys a planer and asks the manufacturer for the speed, he will not run it at 250 or 500 if advised that 375 revolutions per minute is the proper speed. On an emery wheel a few revolutions per minute above or below the proper velocity may mean a great deal in results.

In a test made to ascertain some facts on this point, a machine was rigged so as to give a uniform pressure against the wheel. A piece of steel was cut exactly in half and, with the wheel run at 5000 feet peripheral speed per minute, one of these pieces of steel was ground. Then the wheel was speeded to 6500 feet per minute, and under the same pressure the other piece was ground. It was learned that about 2¾ times the metal per cubic inch of emery was ground at the 6500-foot speed as was ground at 5000 feet per minute, and this same amount of grinding was performed in three-fourths of the time required at 5000 feet per minute.

Making Emery Wheels

Considerable fault has been found by consumers with makers of emery wheels and with dealers in regard to the method of marking the wheels. Tags are sometimes put where they must be torn or removed before placing the wheel in position, and again they come to hand scratched and with figures obliterated,

caused sometimes, very likely, by the supply dealer sending a wheel different from the order and trying to fool the purchaser (sometimes successfully), for it is sometimes difficult to distinguish between two grades or numbers that are almost alike. Small wheels come in an envelope or paper and have no marks, except on the package, and if a wheel is misplaced the shop tool and supply keeper is at a loss to know where it belongs. It would be well to tag every wheel. On large wheels there should be no objection to molding a depression in the side and putting the tag in it and covering the tag with white shellac, so that the printed matter could always be read.

Remarkable Grinding Operation and the Chips

Almost any mechanic, if asked his opinion as to how the chips shown in Fig. 1 were produced, judging from a sample, would invariably state that they were not and could not be produced in that form by grinding as shown.

The part to be operated on, as shown in Fig. 1, was a small spindle. The operation was reducing the end of this spindle from $1\frac{3}{16}$ to $\frac{13}{32}$ inch in diameter for a distance of about $2\frac{1}{4}$ inches back from the end. The wheel used was $1\frac{1}{2}$ inches face, and was first sunk in without traveling until the required diameter was obtained, leaving about $\frac{3}{4}$ inch at the end which was then reduced to the same diameter in the same way. A completely roughed-out spindle is shown lying on the bed of the machine. It was from the first sinking in that the best chips were obtained.

The material from which the spindles were made was about 40 carbon steel, hardened. The work was rotated very slowly, at a surface speed of about one foot per minute, while the emery wheel was run at about the maximum, 6000 feet. The best chips were obtained with the wheel slightly glazed.

During this operation 65 spindles of this description were roughed out and the metal was removed at the rate of $1\frac{3}{4}$ cubic inches per minute. The wear of the wheel, including truing up with a diamond several times, for roughing out the 65 spindles, was only $\frac{3}{16}$ inch in the diameter. The wheel used was 18 inches in diameter, $1\frac{1}{2}$-inch face, grain 46, grade L. Some of these chips were obtained in lengths of two feet or over, with much the same curl as if they had come from the lathe.

Various theories have been proposed as to the cause of these chips. The most likely one seems to be that the rapid removal of metal and the very slow work speed allowed a portion of the particles to become fused together as they left the wheel. It is estimated that probably four times as much metal was removed at the time as was found in the fused chips. While the grinding operation was going on, the particles left the work in apparently

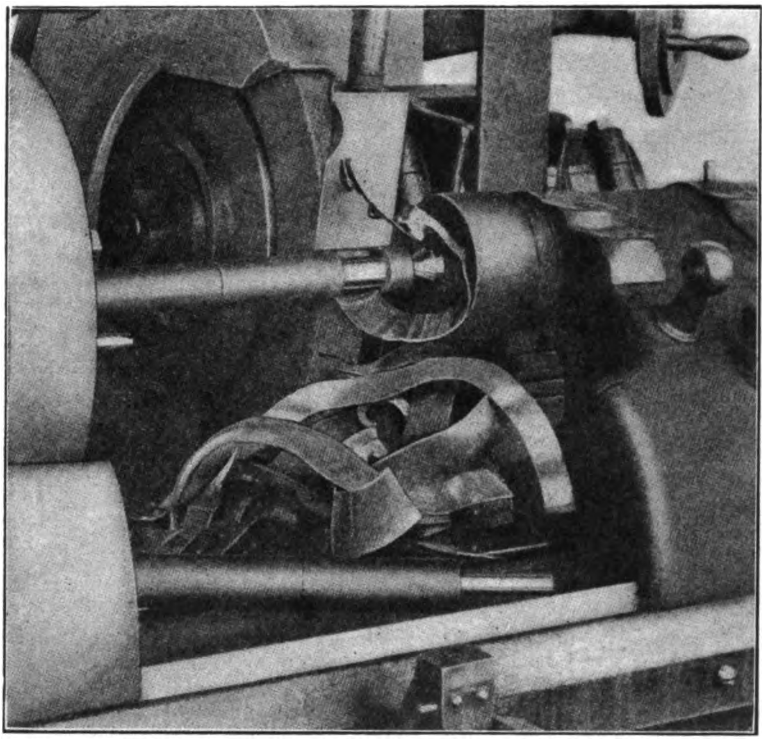


FIG. 1. — Remarkable Grinding Operation and Chips.

a solid red stream of metal, That considerable heat was generated at the point of contact is evident, yet the work was not allowed to become heated.

The work was done on a No. 22 Landis grinder, a 12-inch swing machine. The weight of headstock and footstock was about 500 pounds and of the emery-wheel base 500 pounds. The spindles ground were about 12 inches long.

It has been found to be advantageous to remove this large amount of metal on the grinder, not only on account of the rapidity of removal but also because before, when the end was roughed out on the lathe, and the spindles hardened, there was considerable loss in hardening, the spindle snapping off or cracking near the shoulder, while with the grinding method this difficulty was entirely obviated.

Alundum Grinding Wheels

The Norton Company, of Worcester, Mass., now uses the artificial abrasive "alundum" to the exclusive displacement of the natural abrasive emery in all the wheels it manufactures. This alundum is manufactured by the company in its electric furnaces at Niagara Falls.

Alundum is harder than any known substance except the diamond, and because of its superior cutting qualities has caused the abandonment of emery in the Norton manufactures. It is made by taking the purest amorphous oxide of aluminum found in nature, known as mineral bauxite, purifying it and melting it in the melting furnace in a large homogeneous bath. Upon cooling, the molten fluid solidifies and crystallizes in solid masses of alundum of great purity and of uniform character throughout. Bauxite, the raw material from which alundum is made, was discovered at Baux, France, from which it derives its name, but the purer forms are now attainable in this country. It is interesting to note that this ore is also the chief source of the metal aluminum. The temperature at which the furnace charge melts into a homogeneous liquid mass is above the limit at which temperatures are measured by any means known to science, and is variously estimated at between 6000 to 7000 degrees Fahrenheit.

In the manufacture of the "vitrified" wheels, which the Norton Company was one of the first to engage in, the abrasive materials are mixed with various clays and other substances, and then, after being formed, are placed in kilns, or ovens, and subjected to high temperatures, in some cases nearly 3000 degrees Fahrenheit. Only the purest abrasive will stand this severe heat successfully, and it has been found that there is no abrasive material which works to better advantage, under these conditions, than alundum.

Dressing Emery Wheels to Prevent Glazing

In circular grinding, the wheel is often beveled as at *A* in Fig. 2, in order to lessen the amount of grinding surface presented to the work. This lessens the tendency to glaze, and in internal grinding allows the wheel to pass through the piece being ground easily, with only a small clearance between the work and the chuck.

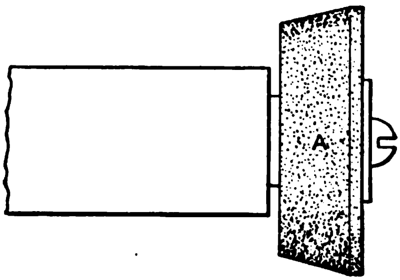


Fig. 2. — Wheel for Circular Grinding.

However, where there is room for the whole wheel to overtravel the work, the wheel should be dressed as at *B*, Fig. 3.

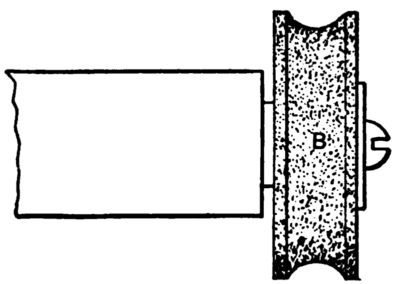


Fig. 3. — Wheel with Two Cutting Edges.

Not only does this form prevent glazing, as does the form *A*, but it has the advantage of two cutting edges, and hence it does not wear away so rapidly.

Of course this method is to be used as an expedient, and used in that manner is good practice, but it is better to select a grade and width of wheel that can be used with the full surface working, both on the score of economy of wheel material and time saved in dressing.

Arbor for Setting Head of Grinder

The sketch, Fig. 4, shows a bar to use in lining up a universal grinding machine preparatory to grinding a hole that is to be

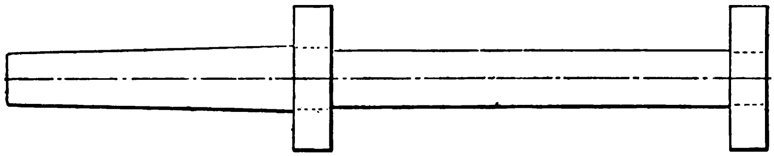


Fig. 4. — Arbor for Setting Head of Grinder.

straight. By inserting the taper end of the bar in the spindle the two collars will run practically true, and when they grind the same size without moving the wheel, the head spindle will be in line with the ways. This method is common practice, except

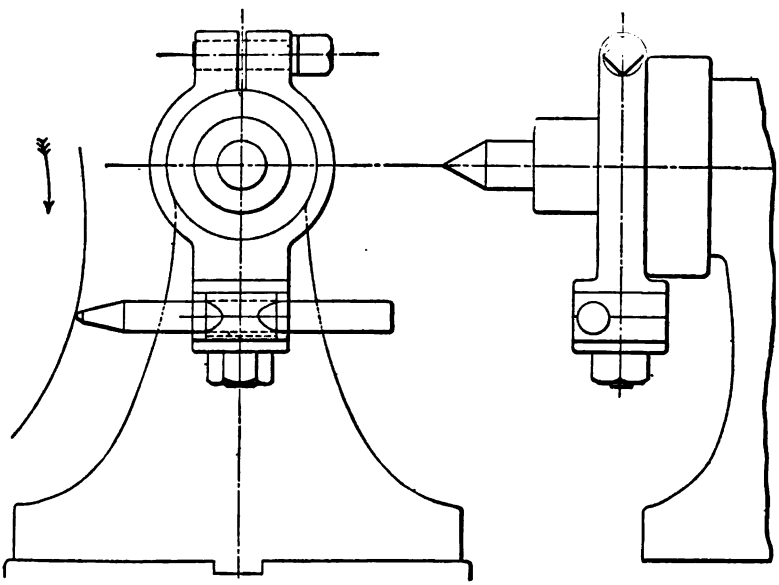


Fig. 5. — Wheel-truing Fixture for Grinder.

that a piece is usually held in the chuck and must be trued up each time it is used. Often a piece is ground its whole length — an operation that consumes much more time than the plan suggested.

Wheel-truing Fixture for Grinder

Figure 5 shows a fixture for holding a diamond. It is attached to the footstock and is convenient, for the reason that it enables the operator to dress off the wheel without removing the work from the machine or removing the steady-rest from its position

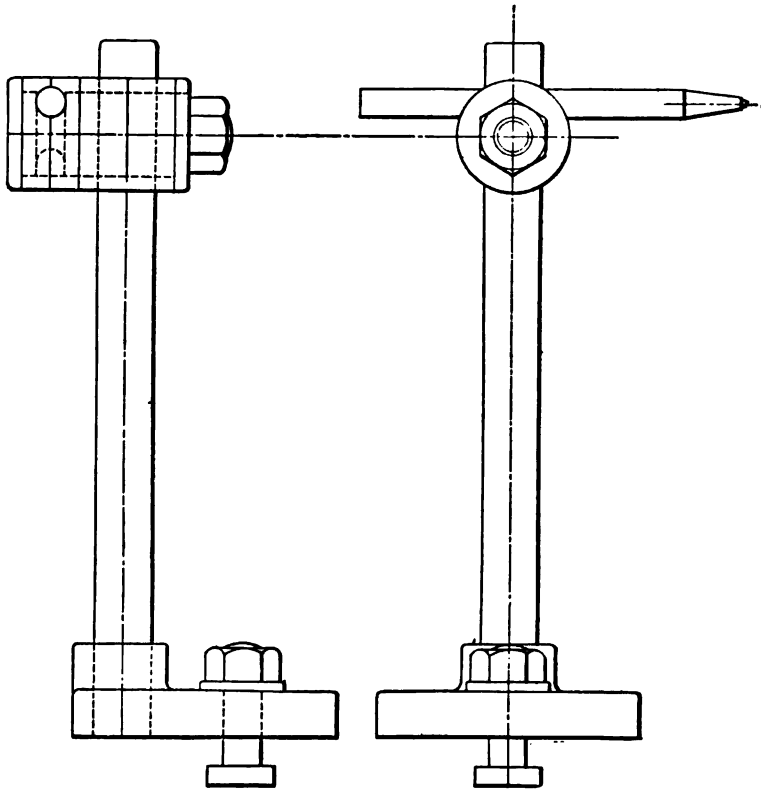


Fig. 6. — Wheel-truing Fixture for Grinder.

on the bed of the machine. It is a time-saver, and might well be furnished with the machine.

In place of the diamond holder usually furnished with a universal grinder, one is shown in Fig. 6 that can be used in either machine. Being adjustable in every way, a sharp corner of the diamond can be brought into position to use, and the vertical adjustment is quite an advantage on a surface grinder,

as it admits of truing the wheel without altering the adjustment of the wheel spindle.

An Emery-wheel Cabinet

The cabinet shown in Fig. 7 was designed to provide a suitable place for emery wheels which had accumulated until their disposal became a problem. The upper drawer is 2½ inches deep and contains all the wheels for internal work. The upper row inside is for 6- and 7-inch wheels for surface grinders; a partition is placed in the rear of this compartment, and a drawer fitted in

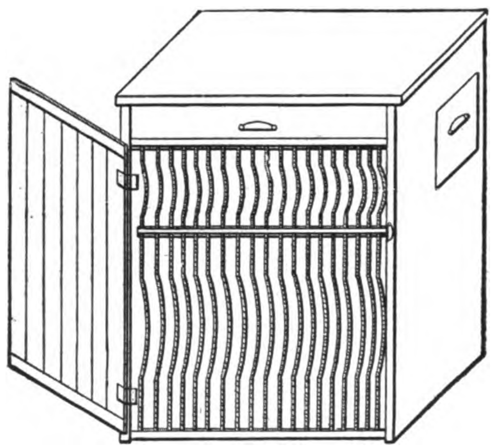


Fig. 7. — An Emery-wheel Cabinet.

the side to utilize the remaining space. The lower row is for 12-inch wheels for universal grinders; an inch is allowed in depth and hight for clearance. The partitions are ½ inch thick, ⅝ inch apart for ½-inch wheels, and are cut out so that easy access may be had to any of the wheels. The bottom is sawed about ½ inch lower at the back, so that the closet will tilt slightly backward to prevent the wheels from rolling out.

To Cement Emery Cloth to Polishing Disks

Apply quickly to the disk with a broad, flat brush a coat of moderately thick shellac varnish. Lay on the emery cloth and

place under a press at once. The shellac varnish must be clean and without lumps, as these may not be pressed down to an even surface and so cause scratches in the work.

Substitute for Cement on Grinder Disks

A good substitute in place of glue or various kinds of cement for fastening emery cloth to the disks of grinders of the "Gardner" or "Besly" type is to heat or warm the disk and apply a thin coating of beeswax; then put the emery cloth in place and allow it to set or cool under pressure.

Speed of Buffing Wheels and Grindstones

Wood, leather covered..........	7,000	feet	per	minute
Walrus hide	8,000	"	"	"
Rag wheels	7,000	"	"	"
Hair brush wheels	12,000	"	"	"
Ohio stone	2,500	"	"	"
Huron stones..........3,500 to	4,000	"	"	"

Rig for Grooving and Rounding Emery Wheels

Figure 8 shows a rig for dressing arcs on emery wheels. It saves time, as when once set it dresses a true arc, which one does not have to touch up afterwards. By sliding the diamond-holder along the slot from the center one may secure any arc, male or female, and no emery can get into the working parts. *A* and *B* are a nut and bolt for holding the top and bottom pieces together, and they should be adjusted so as to work nicely without play. *C* is a nut for fastening the diamond-holder when set to the arc wanted. The rest of the sketch is plain enough to be understood easily. *S* is the handle of the fixture.

Grinding and Grinding-machine Rests

One of the most important things in connection with grinding is the manner in which the work is supported. The rests which are described and illustrated herewith are the outgrowth of several years of grinding practice and are in use at the present time. We do not claim they are perfection, but have never seen anything better.

Design of Grinding-machine Rests

Now the idea in the rest problem is this: Whenever there is a sufficient amount of one kind of grinding to do, have a special rest made to do it. Have the rest made in one piece, holding a certain number of shoes instead of rigging up with individual

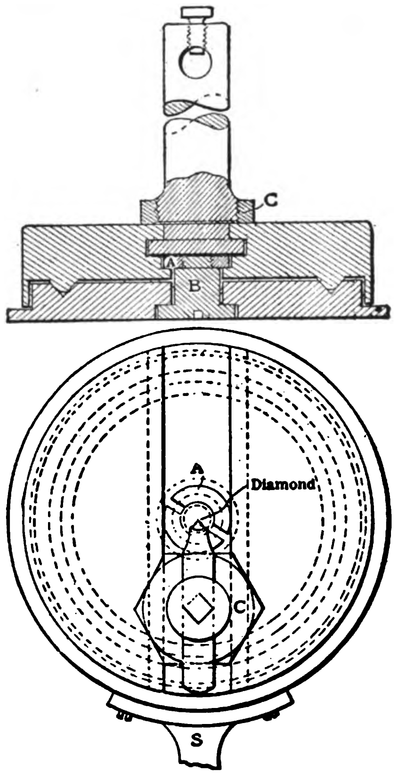


Fig. 8. — Rig for Grinding and Rounding Emery Wheels.

rests. Rests have been made up to 20 inches long, holding eight shoes, and this arrangement has been found the best practice. One reason for having the rests made in one piece is that greater stiffness is thus gained, and the whole thing in grinding is to have everything as stiff as possible.

Figure 9 shows a standard pattern of rest. This does not cost very much to make; all the finish there is on it is on the bottom

and on the top, on the under side of the cover and in the slots. Great care is exercised in planing the slots to get them all alike, so that the shoes will interchange. The ledge *A* on the cover is to keep the water from running back over the rest. The nut *B* on the screw *C* pushes the lead shoe forward as it wears. The slot *D* in the bottom is to allow the rest to be used as a clamp rest when necessary. Four bolts hold the cover down onto the shoes more firmly; for a longer rest more bolts should be used.

The shoes are cast in gray-iron molds and nice clean castings are obtained, requiring no finish. Half tin and half lead is the composition used. The shoes are about 8 inches long, and are

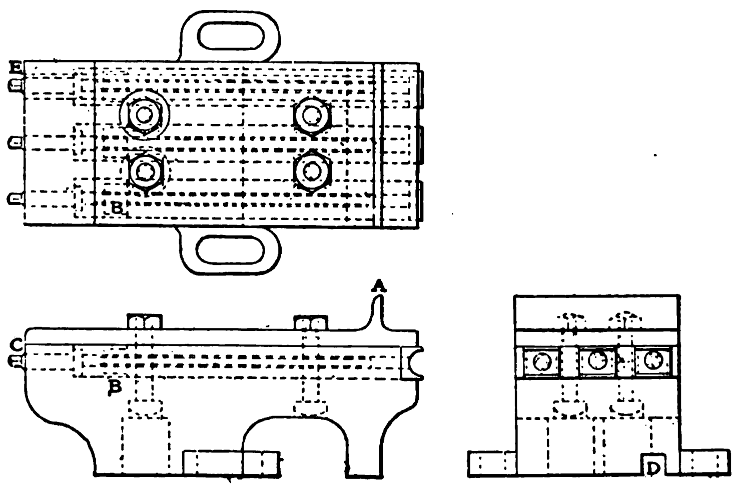


FIG. 9.—Standard Parts of Work Rest.

used until there is only 2 inches left. All scrap is saved and remelted. We have over a hundred varieties of these rests with different combinations of shoes. The shoes are all made in standard sizes. They are 1 inch thick, and in width run from 1 inch to 2½ inches, varying by quarters.

METHOD OF GRINDING A TAPER PIECE

Figure 10 shows a piece of work of which thousands have to be made. These pieces come from the blacksmith shop .010 inch over size. End *A–D* has a limit of error of .001 inch, and *B–D* of .003 inch. After being pointed and straightened *A–D* is ground,

using the standard pattern rest with two shoes 1½ inches wide and a 36 x 2 inch emery wheel running at a surface speed of 6000 feet; .007 inch is removed in two cuts at the rate of 600 pieces per day. The pieces are then hardened on the point *A*, and then finish ground with the rest rigged up in the same manner as the rougher, only using a set wheel passing over once and back, removing .003 inch and bringing them to finish size. They are then taken to another grinder and *B–D* ground, using a four-

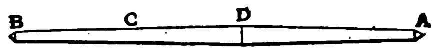


FIG. 10. — Duplicate Grinding Operation.

shoe rest. Three shoes 1½ inch wide bear on the part being ground, and the fourth, a narrow one, cut down to ½ inch wide on the end, bears on the part previously ground, serving as a steady and keeping the two sections in line. The narrow rest bears close to the shoulder *D;* .010 inch of stock is removed during this operation in two cuts, passing over the work four times. After this grinding the pieces are straightened and ground at *C–D*, using the special rest, Fig. 11.

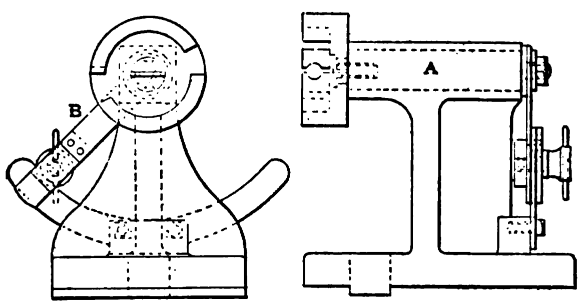


FIG. 11. — A Special Grinding Rest.

A Special Rest

This rest was designed especially for this operation. One bearing is above the work and the other below. The shoe is turned with its carrier *A* by the handle *B*, which is clamped by the thumb screw *C*. To put in a piece of work the operator swings the handle up, puts the work on the centers, brings the handle down until the shoe bearings touch the work, starts the work up, brings the handle down tight and clamps it, and then

proceeds to grind. The object of this grinding is to produce a true round spot on each piece with no variation in the taper. A small universal grinder is used for this operation. After the operator has put the work into the rest he brings the wheel up at *C*, Fig. 10, just sparking the work and grinds by *D*, removing about .002 inch at that point as the taper is set a little nearer parallel than when grinding *B–D*.

The reason for using this style of rest is that variation in the size of the work will not affect the taper being ground. This rest

Fig. 12. — Concentric Grinding Operation.

having one support underneath and the other above the work, the variation in size does not prevent the work from bearing properly in the rest, as the operator pushes the handle down for each piece with the same pressure. The portion ground comes inside the shoe bearings, the wheel not touching where the shoe bears on the work. A flat center is used in the tailstock spindle, allowing the piece to adjust itself to its own center. The shoe is made of brass, and will run for a month at a time without being touched or changing taper.

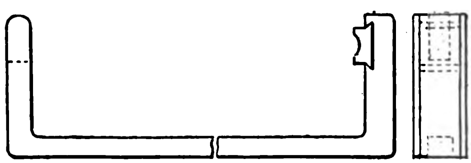


Fig. 13. — Clamp for Standard Pattern Rest.

Use of the Clamp Rest

There are lots of jobs of grinding on which a clamp rest is used to bring different surfaces ground concentric. Fig. 12 shows such a piece of work. End *A* is ground first and then *B*. When grinding the latter a five-shoe rest is used, four on *B* and a clamp rest on *A*, close to the shoulder. Fig. 13 shows the clamp used in connection with the standard pattern rest; it is a sliding fit in groove *D*, Fig. 9. Fig. 14 is a wedge which the operator drives in between the clamp and the rest at *E*, Fig. 15, bringing the clamp up tight on the work.

Fitting up New Shoes for the Rests

When rigging up or putting in new shoes the operator files out a V in the end of each shoe, puts the shoes in the rest, places a reamer the size of the finished work on the centers and reams the shoes so that they will fit the finished piece. On universal grinders, used for fine finishing, the shoes are all saved. Say, for example, that the operator has been given some stock to grind down to $1\frac{3}{8}$ inch having .004 to remove. This being a special job he will use individual rests, requiring four, and will proceed like this: Picking out four new shoes, he places them in four rests; then placing a $1\frac{3}{8}$-inch reamer on the centers reams the

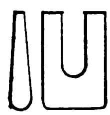


Fig. 14. — Wedge for Rest Clamp.

shoes one by one; then removing the reamer places his rests on the machine and proceeds to grind. After finishing the job he will remove the shoes and mark them "$1\frac{3}{8}$- inch stock to grind."

Fig. 15. — Job for Center Rest.

Handling Work in the Center Rest

A center rest with hollow spindle in the headstock comes in handy around the grinder. A job, Fig. 15, had to be done with the center rest and hollow spindle. *A* is the bearing and must run dead true with portions *B* and *C*. They were four feet in length, and after roughing all over in the large grinder and finishing *B* and *C* it was found that *A* could not be finished good enough there, so that the pieces would run perfect. The largest universal grinder then in the shop would take in only 24 inches; so the following scheme was devised and worked to perfection: On one grinder there were a hollow spindle and chuck and two center rests built exactly like a lathe center rest. The hollow spindle

was put in, the chuck put on, the piece placed in the chuck with shoulder *D* resting against the chuck, and the center rests then located at *E* and *F*, leaving the end *C* to run free. As there was only .002 to remove, the work was run slowly, so as not to cause any vibration in the end *C*, then a wheel was put in suited to the conditions under which we were going to grind, and we went ahead and came out all right. A hollow spindle and chuck can be used on quite a few grinding jobs. For example, one job we have is a piece 4 feet long, and after being ground straight all over one end has to have a taper 2¼ inches long ground on it. Now one can do this job on a short grinder, saving floor space and the cost of a longer grinder. The grinder we use will take only 2 feet, but is rigged up with a hollow spindle and chuck, clamp rest and spring tailstock. This gives a stiff support for the work and turns out work just as good as if it were ground on a longer grinder on centers.

Special Center for Tailstock

On plain grinders, grinding such work as Fig. 15 what is called a multiple center may be used. The tailstock moves crossways of the grinder plates, and all adjustments for length are got by moving the headstock. In the tailstock is used a center 1-inch diameter with ten center holes in it, and as fast as one center burns out the operator turns the center around to the next hole, drives it back and goes ahead with the grinding. On small work running fast, this has been found to be the best practice, as centers do not last long, and with a center with only one hole there is a great waste of steel.

A Suggested Improvement in Grinder Design

There is one thing about the grinder that could be changed to advantage, though so far only one builder of grinders has adopted this modification. Design the grinder platen so that the T-slot will not be in line with the centers, but about three inches toward the front of the machine. This will admit of a design of rest that can be fastened to the table by means of bolts underneath the rests and not on the sides. Individual rests could then be placed side by side. A grinder built in this manner is found much handier than the style with the T-slot in line with

the centers. Many other advantages develop with the new design the more this grinder is used.

Magnetic Work-Holder for a Disk Grinder

The engravings Figs. 16 and 17 show an extremely useful addition to the ordinary disk-grinding machine, for holding iron or steel articles.

It consists of four round *permanent* magnets *A*, contained in a non-magnetic holder *B*, the magnets being secured together at the ends by the plate *C*, the plate acting as a keeper and completing the magnetic circuit at the end. The other ends of the magnets are flush with the face of the holder. The holder is mounted on the base *D* and can be adjusted to any angle in a

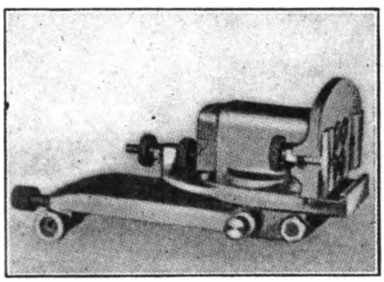


Fig. 16. — Magnetic Chuck for Grinder.

plane parallel with the base. It is fixed in its normal position, viz., with the face of the holder at right angles with the side of the base, by means of the stop-pin *E*, and in any other position it is held by the clamping screw *F*, which, the base being split, tightens on to the turned shank of the holder. A movable rest *G*, adjusted by the two nuts *H H*, supports the work against the cutting action of the emery disk while being ground, and side stops *J* or *K* prevent any lateral movement of the work across the face of the magnets.

The base *D* rests on the table provided with the machine, the planed edge being held up against the guide strip or the table, the whole device being moved toward the grinding disk by hand. An adjustable stop-screw *M* limits the distance between the disk and the face of the holder by coming against the edge of the

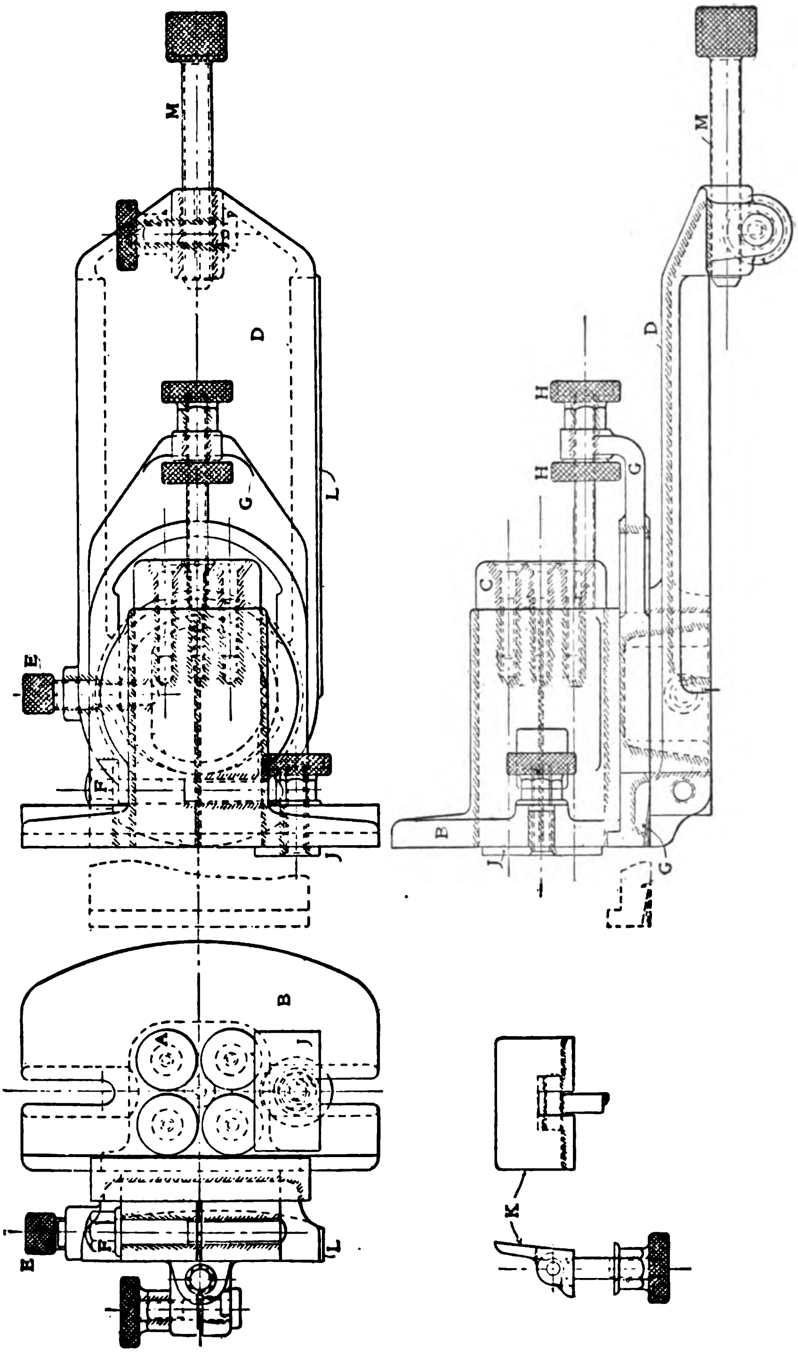


FIG. 17. — Magnetic Work Holder for Precision Grinding.

table, thereby insuring uniformity in the thickness of the work ground. By means of the angular adjustment referred to, or the angular adjustment of the table, or both, articles of various shapes can be ground.

When necessary for very accurate parallel work, it is an easy matter to true up the face of the holder and the ends of the magnets together on the machine the device is being used on, and work has been ground by this means which has not varied more than .0005 inch from being parallel, which is probably as near as can be expected from that class of machine, the error being probably due more to the grinding medium than to the device. Again, work only .020 inch thick has been successfully held and ground without trouble. Articles can be held until red-hot, if so desired, without detriment to the holder, and a vigorous shake is all that is necessary to detach the pieces into a bucket of water; or the whole device, with the work attached, can be dipped. It is only the work of a moment to fix another piece.

Of course the same results could be obtained by other forms of holders, and, in fact, several such had been made before this one; but none were so simple or so easily handled, the weight complete being only 5½ pounds. A doubtful point at the time of making the first was whether the magnets would retain their strength for any length of time, owing to the vibration of the machine, rough handling, etc.; but after it had been in use for a number of months, it was the same as when new. A spare set of magnets, however, should be kept ready for insertion should they be required, and the change can be made in two or three minutes.

Surface Grinding and the Magnetic Chuck

The plate and fingers were formerly used to pinch the work down, and what questions would arise in the mind as to the causes that led to the steel working into such shape? On the next job the operator would try shellac, take the work off, find it in the same shape — and, worst of all, it was .0005 tapering, for with all his care dirt would get under it. And it meant at that time a lot of lapping.

The work would not be tapering all of the time, but how many times have we looked at a shellacked piece of work with a shudder over the possibility of a piece of dust being under it.

But with a magnetic chuck it is all different. One thinks nothing of taking a piece of work off, measuring it, putting it back and grinding .0001 inch more off; and it is easier than lapping. This has been disputed by good mechanics; they said it was impossible to put it back and do that. But when it was done for them they were converted.

When grinding, one will get so he can tell by the sound of the wheel whether it is cutting all right. Lots of times it will take a "bite" and he will lay it to a loose spindle, so he tightens it up. The wheel comes to a stop. If he had stopped to think that the

FIG. 18. — The Work to be Ground.

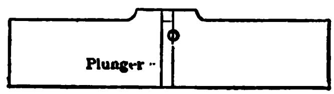


FIG. 19. — Plunger.

man before him did a good job and he took the machine from him, in fact waited for five minutes for him to finish his job, he must have known it couldn't have been a loose spindle. Then he changes the wheel and instead of truing it up properly and giving it a chance even if it isn't the proper wheel, trues it off crowning, and instead of having a million or more cutting points has just enough to start off. Then the wheel glazes in spots or on the complete cutting circle, and the trouble begins. When

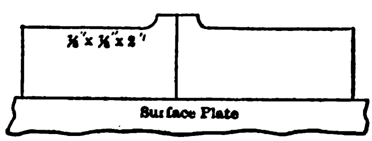


FIG. 20. — Surface Plate.

a wheel glazes it will work when it is cutting as if it was sinking into the work; but did you ever stop to think of the steel swelling because of the heat due to the glazed wheel raising the surface and increasing the sparking?

It is a pretty massive piece of metal that will stand a cut .002 inch in depth with a free cutting wheel without permanent distortion. A cut that deep on cylindrical grinding means good cutting with lots of water, but water in surface grinding has no effect so far as keeping strains out is concerned, but has a good effect on cutting edges to keep the heat low. With a fine cutting

wheel a magnetic chuck will absorb and dissipate the heat fast enough on this work.

There is no trouble in holding without distortion thin pieces like Fig. 18, which are finished .045 x .75 x 4.5 inches, and have only .00015 inch left on all sides to lap clean of wheel marks. And they have to be square and parallel, as they are for type mold plungers. Now to make the job a little easier it is necessary to bring the surface so that the round nick at the end, which

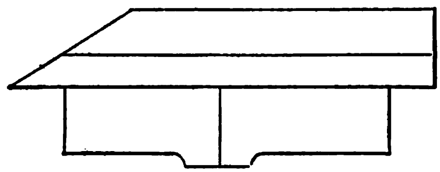


FIG. 21. — Parts to be Tested.

is part of a .095-inch hole, comes a certain depth and hight respectively from the latter. The rest of the hole is in a water jacket, Fig. 19. This forms the nick in the type — and type metal will throw a bur in a space of .00005 inch.

To show the refinement in testing these for right angles, it should be stated that they are put on a surface plate with faces

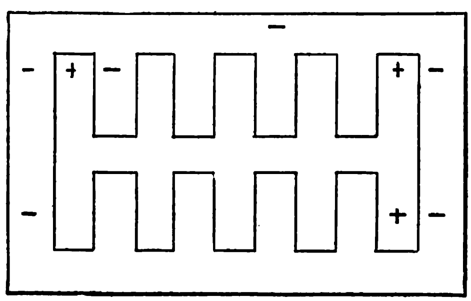


FIG. 22. — Showing + and − Poles of Chuck.

together like Fig. 20, picked up and tested as in Fig. 21, and have to shut out light in any way they are put together. If they do this, each is pretty near square. The water jackets placed end to end like Fig. 20 multiply the error four and one-half times. The surfaces are squared with a knife edge square independently of each other. The test proves the squares at the same time.

Figure 22 shows the + and — poles of the magnetic chuck. It is well to remember that the surface having the greatest area

of contact determines the way the work is pulled by the magnet. Fig. 23 shows an end view of a job lengthwise of the chuck. This is a fine way to square up parallels or similar work using a block *A*, Fig. 24, as a back rest and placing it on the block. *B* is on the — pole with a piece of drill rod under the work, and another piece between the work and *B*, as shown. The pull is all on block *A*, Just try to pull it off and see if you haven't confidence in it. This can be used on the ends of the chuck just as well as lengthwise.

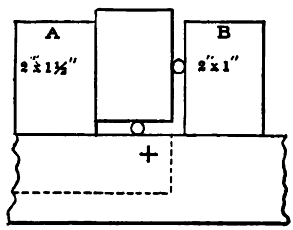


FIG. 23. — End View of Job.

Adopting a handy thickness for block *A*, its application is very extensive. Tapers can be ground by bringing the sides parallel and using a wire for roughing one side of the taper on a master taper, then removing the wire and finishing on the master taper direct. Fig. 25 shows a pair of angle irons — of the pro-

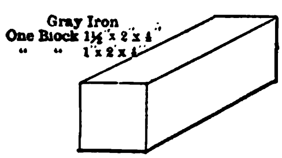


FIG. 24. — Back Rest.

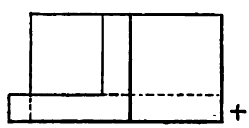


FIG. 25. — Pair of Angle Irons.

portions shown in Fig. 26 — for squaring off the ends of pieces, a piece of thick paper being placed between + and – angle irons. Use a piece of drill rod to rest the work on. Fig. 27 shows a way of blocking a high piece *C*. It requires an angle iron with a brass piece *D* soldered on, which makes a good support for work ¾ x ⅜ x 5 inches. A piece ¾ x ¾ x 5 inches will stand on its own bottom without the arm on piece *D*. Fig. 28 is a jig that was so long it would stand only on the – pole and so the operator made contact with the + pole with rough square iron in the way

shown and ground the top surface without any trouble. Fig. 29 shows how to hold work on parallels, using the back contact. The piece *E* was put on and found to work better than the broad contact, as it did not have such a pull sideways; it is $\frac{1}{16}$ inch thick finished steel stock.

These little tricks work well on gages or odd jobs of good grinding. In manufacturing in quantity, the chuck is the ideal bed for fixtures, and boys can do good work on it and plenty of it.

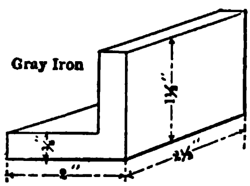


FIG. 26. — Proportions of Angle Irons.

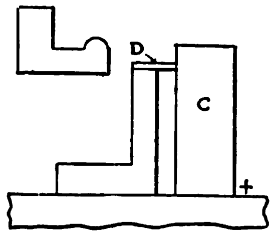


FIG. 27. — Blocking a High Piece.

Figure 30 is a hint for machine builders. Don't be afraid to divide the thousandths into tenths on surface grinders. A man has carried a piece of tin like *F* for years, has clamped it on different machines and worked to it, and it has not failed yet in two or three thousandths of movements of the hand-wheel. Fig. 31 is a spring placed on the hood of a Brown & Sharpe No. 2 surface

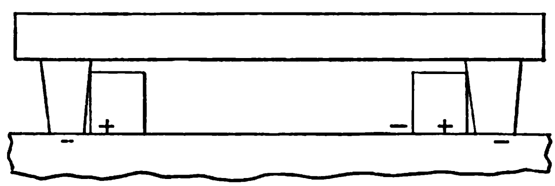


FIG. 28. — A Long Grinding Jig.

grinder, for taking end thrusts and giving excellent results for side-wheel grinding. It is lined with fiber $\frac{1}{8}$ inch thick.

Don't try to lap with a steel disk, or use steel disks for a web with thin emery disks glued on; the reason is obvious.

A handy way to true up a wheel is to put the vise that comes with the grinder on to the chuck and hold the diamond holder in it.

Finishing cuts should be taken without the current on when practicable.

Hardened steel is the ideal for the small angle irons and parallels; emery does not bed in them so. Keep the brush off of the face of the chuck; it charges with emery and cuts the babbitt insulation. Use a flat stone to take out the bedded emery; rub lightly and a small piece of emery will feel like a solid shoulder.

Making Emery Polishing Belts

The following account of the method of coating emery belts which has been followed with success in needle works may be of

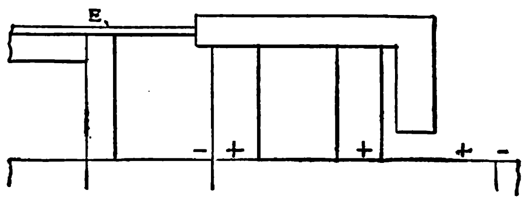


Fig. 29. — Holding Work on Parallels.

assistance to those requiring information on the subject. Two operators are required, and the tools consist of a 6 or 8 inch

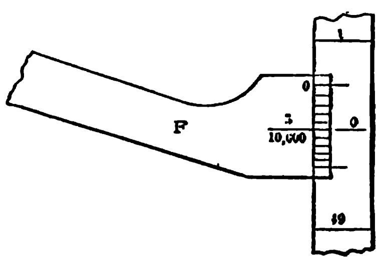


Fig. 30. — Hint for Machine Builders.

pulley and two sections of broom handle about 18 inches long. The emery — preferably hot — is held in a shallow box of suitable size, which is placed on a table or bench of such width that the operators may work from opposite sides. A support for one end of each of the sticks is provided in order to leave one hand of each operator free while applying the glue, which is done with a wide brush by one, while the other feeds the belt around, thus making this operation a matter of a few seconds. The glue being applied, the sticks are grasped at both ends, the belt drawn taut, and the operator on the pulley end leans forward and brings the pulley

down smartly into the emery, at the same time drawing it toward him, the operator on the other end, of course, following his motions, this being repeated as often as necessary to cover the belt. The weight of the pulley serves to imbed the emery in the glue better than if it were merely sprinkled on the belt.

The belts are then hung up till perfectly dry before using. These belts are about four inches wide, with about six feet length of a surface, which is always coated at one operation.

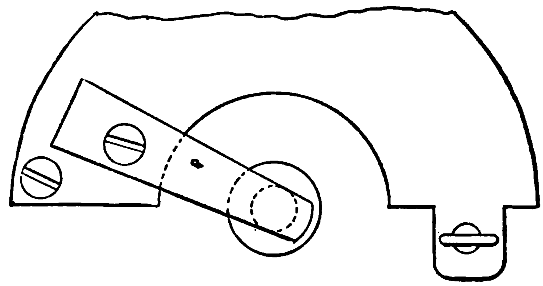


FIG. 31. — Hood Spring for B. & S. No. 2 Surface Grinder.

SIMPLE DEVICE FOR SHAPING AN EMERY WHEEL

It is often necessary, in grinding, to use an emery wheel having a true concave or convex edge or periphery.

A few years ago we were interested in the manufacture of bicycle chains in large quantities, the heads of the rivets being

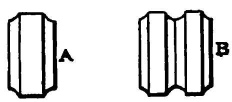


FIG. 32. — Roller for Spinning Rivet Heads.

"spun" on by a pair of small rollers, *A*, Fig. 32. When two of the rollers were placed side by side, as at *B*, the corners combined to make as perfect a semicircle as possible. When through use the rollers became worn or "pitted" they were reground, and were thus used over several times. For the sake of economy and ease of adjustment, two or three dozen rolls or "spliners" would be ground at one time and accurately enough, so the face of one roller would match perfectly with the face of any other in the same lot.

A forging was made and drilled through at *C*, Fig. 33, a binding screw being added at *D*, which held and clamped the diamond turning tool at any distance from the center line *E*; the lower end of the forging was turned with a shoulder at *F*, and made a neat working fit when inserted in one of the tooth rest holders supplied with the grinding machine. If a roller for forming a rivet head with a radius of, say, ⅛ inch was required, the diamond truing tool was clamped in position with the point *G* ⅛ inch back of the center line *E*; the tool was then fed against the wheel by

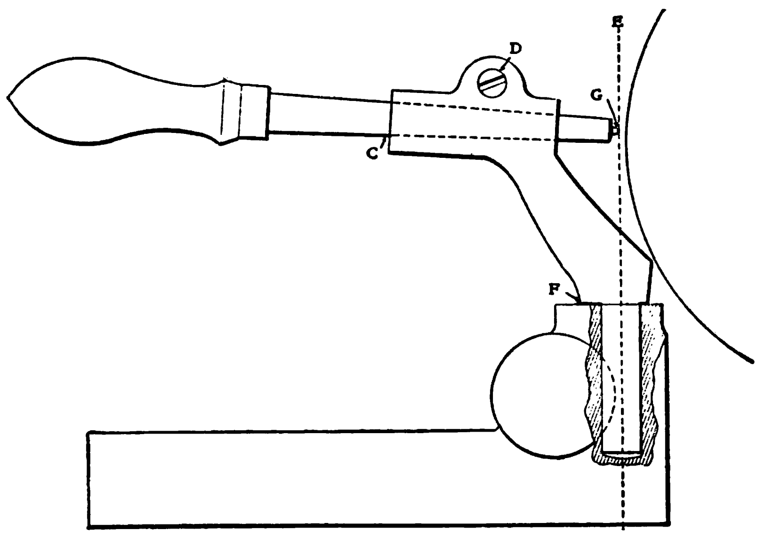


FIG. 33. — Roller Grinding Rig.

the cross feed, and the handle *H* was swung slowly around by hand, turning the edge of the emery wheel to the desired radius.

With this holder a wheel could be produced with any radius from 0 to 1 inch, which was very handy when grinding out the flutes of taps, "touching up" milling cutters, forming tools and other odd jobs.

By setting the diamond "by" the center line, a wheel with a concave edge was produced.

GRINDING IN A VALVE

The man who is sent out from the shop around the country doing repair work cannot carry many tools with him, and con-

sequently often has to "rig up" for a job. Recently one had to re-grind the exhaust valve in a small horizontal gas engine, and because he did not know what the job was when he started he took no tools. The valve seat was cast integral with the cylinder and was about three inches from the outside of the engine. There were two spanner holes in the valve. He sawed off about six inches of the handle end of an old baseball bat, and drove two nails in the end to fit the spanner holes. He took a brad-awl and used it for a pivot bearing at the other end. Then with a piece of cord and a pine stick he improvised a bow-driving device and

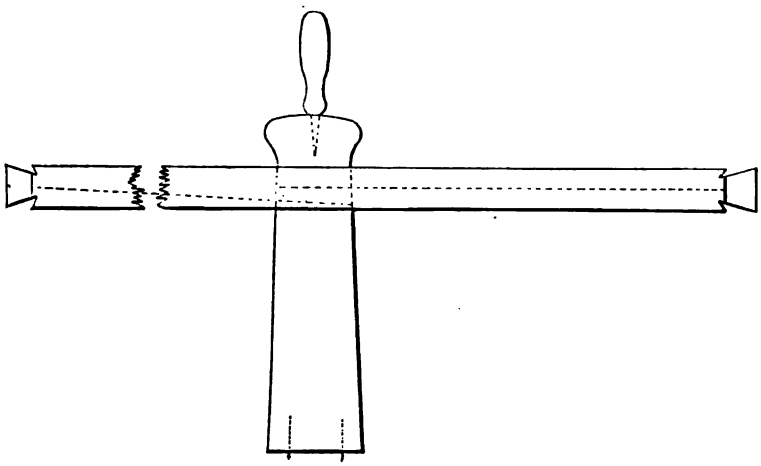


FIG. 34. — Rig for Grinding Valve Seat.

ground in the valve quickly and easily. There was not more than six inches of room back of the cylinder. The sketch Fig. 34 explains the tools clearly.

PRACTICE, FIXTURES AND TOOLS FOR ROLL GRINDING

Figure 35 represents one end of a roll made of 8-inch steel boiler tube No. 10 gage. The heads are of cast iron, with steel journals $1\frac{7}{16}$ inches diameter, pressed in; the cast-iron head is turned, pressed into the tube and pinned. Up to this point the making of this roll is a plain, simple job; the finishing, however, is quite another matter. It is necessary that the surface of the tube be made true and smooth, and therefore the first thing to do is to straighten it. To do this it is placed in a special machine

on centers. This machine is supplied with a hydraulic press mounted on a truck which can be run from end to end of the machine. Blocks, Fig. 36, made of steel castings and bored to the diameter of the tube, are used, placing one or two of them under the tube, as may be required, and one on top under the ram of the press. The straightening is done by pressing, by which operation the bends are removed, the tube is rounded up, the humps are pressed down, and many of the hollows are raised.

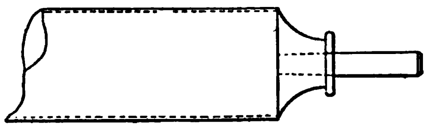


FIG. 35. — Roll to be Ground.

It takes few words to tell what tools are necessary, and how they are used, but to do the work and to do it right requires considerable skill, and much practice is necessary to become an expert. The thickness of the stock in the tube will not admit of the surface being turned without making the roll too weak; therefore it is necessary to straighten it as nearly perfect as possible, so that the surface may be ground smooth and true. This grinding is not a simple job such as grinding a solid piece which has sufficient stability to admit of the emery wheel being pressed to the work and the surface rapidly removed.

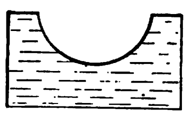


FIG. 36. — Grinding Block.

The roll shown is 160 inches long, it could be ground in any grinding machine of sufficient length, but the time required, and the possibility of doing the work in a much less expensive machine and in less time, led to the designing of a grinder for the purpose. It was found by experiments with the regular grinder that it would be necessary to support the roll in some way in order to prevent its springing away from the wheel and chattering. It was found that when the emery wheel was forced against the roll hard enough to make a fairly heavy cut, using one wheel, on one

side only, the roll would spring and tremble so much when at or near the middle, that the wheel would touch at intervals only, making a very rough, chatter-marked surface. This was overcome by a pair of follow rolls, as shown by Fig. 37. These rolls are about 4 inches long, and are at one side of the emery wheel, or rather the advance ends of the rolls are in line with the side of the wheel and follow the cut. This arrangement prevented the roll from springing away from the wheel, and also stopped the chatter, enabling a smooth surface to be obtained in a reasonable time. It was impossible to force the work beyond a certain point, as the roll became heated at the point of contact with the emery wheel, making a very poor surface.

Even with a flood of water the heat would be so great that the surface would turn blue. With the emery wheel, which is 14 inches diameter and 2 inches face, running at 2,000, and the roll 8 revolutions, and a feed of ½ inch per revolution of the roll, it

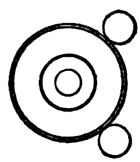


FIG. 37. — Follow Rolls for Grinding.

takes five hours to finish one of these rolls and have it sufficiently smooth and true for the purposes for which it is to be used. It is doubtful if it be possible to find by experiment a wheel, speed or feed that could do better or more rapid work. With one emery wheel 120 of these rolls have been ground, the best and most rapid work being done when the wheel was worn down to 12 inches. It was kept in use when it was worn to 7 inches.

In starting the cut at the end of the roll, the follow rolls are not in contact at all, care being taken to grind in one spot until a true surface is obtained, in order that the follow rolls may be able to follow on a comparatively true surface and return to the starting point on the same surface. Before starting on another cut, care is again taken to true up the end. The feed used, and the size of wheel, do not seem to correspond with the usual practice. This job of grinding does not require to be as nearly perfect as does a lathe spindle, or work of that class. It is not

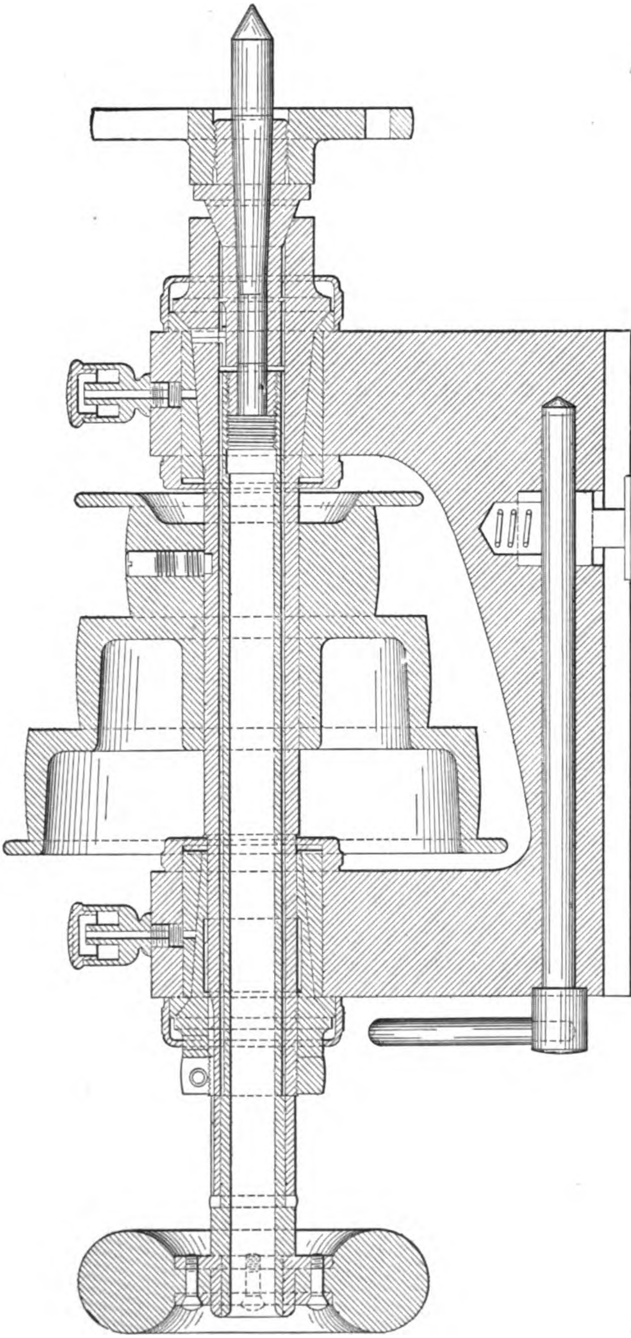


FIG. 38. — Bearings and Spindle of Bench Lathe Head-stock.

found necessary to true up the wheel at all, as it keeps a sharp and approximately true surface without this being done.

Precision Grinding

Among the products of the Pratt & Whitney Company is a line of small precision machine tools, among which are a small bench lathe, of the type made by various watch-tool companies, and a small milling machine of the knee type. These machines are representatives of the very highest degree of accuracy obtained in commercial work of any kind, and the processes employed in their production are interesting in the highest degree. The following relates to the methods used in the construction of the bearings and spindle of the lathe head-stock.

Figure 38 is a longitudinal section of this member, from which the character of the work to be done will be apparent. The bearings will be seen to be made of inserted bushes which are of hardened steel, are whole, and have two tapers which are laid out to approximate the Schiele curve. The corresponding journal at the work end of the spindle is integral with the spindle; but at the rear end is a separate bush which is adjustable endwise for wear. Draw-in or collet chucks are used to carry the work when this is made from a rod, and also to carry the face plate and center as shown in the engraving.

The making of the spindle — with the exception of the collet seat — presents no unusual features, the journals being ground on a universal grinding machine. The holes in the head-stock body for the reception of the bearing bushes are lapped with a long lap passing through both at the same time, whereby truth in alinement, roundness, and correct size are secured. The bushes are hardened and are then relieved from hardening strains by warming to a temperature at which water will "skate" off the surface, or, in other words, assume the spheroidal state. At this temperature there is no drawing of the temper — the bushes being glass hard — but long experience of the Pratt & Whitney Company has shown that this warming of the pieces does release the hardening strains. Bushes so treated may be subjected to the finishing processes with the certainty that they will not thereafter change their size, whereas, without this warming, the permanence of the size is a matter of the greatest uncertainty.

Some of those engaged in this work consider that the warming only releases the hardening strains up to the temperature employed, so to speak. In other words, they consider it probable that, were the piece to be again heated above the skating temperature, further change in size would probably result; but as the temperature employed is beyond anything which the parts will ever again experience without absolute abuse, the practical effect is to remove all tendency to change their size.

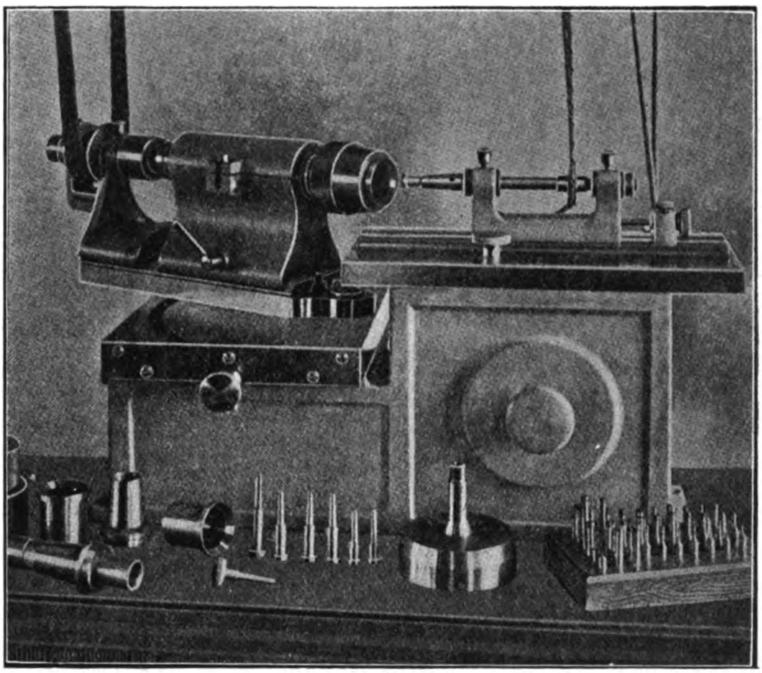


FIG. 39. — Grinding Machine with Bush in Place.

GRINDING BUSHES

After this treatment the bushes are ground upon the outside to standard size and to fit their seats in the headstock, and are then ground on their inner surfaces by the small special bench grinding machines shown in the half-tone illustrations. Fig. 39 shows one of these machines clearly with a bush in place in the machine, and with several other bushings and other pieces of

work on the bench. At the right will be seen, set in a wooden base, an assortment of diamond "laps" with which the work is done.

The bush to be ground is in a chuck on the end of a spindle mounted in a head which again is mounted on a swivel base by which adjustment of the angle is obtained. The chuck employed is a special design for this purpose, and is shown in Fig. 40. The body *a* fits the spindle of the work-carrying head by the regular taper fit used with collects; but it is, of course, solid. The chuck is bored out — or rather ground out — to receive the standard bushes to be ground by a snug sliding fit. Three openings are cut through the body, as shown at *b c d*, into which three jaws *e* are dropped. Openings and jaws are wedge shaped, so that the

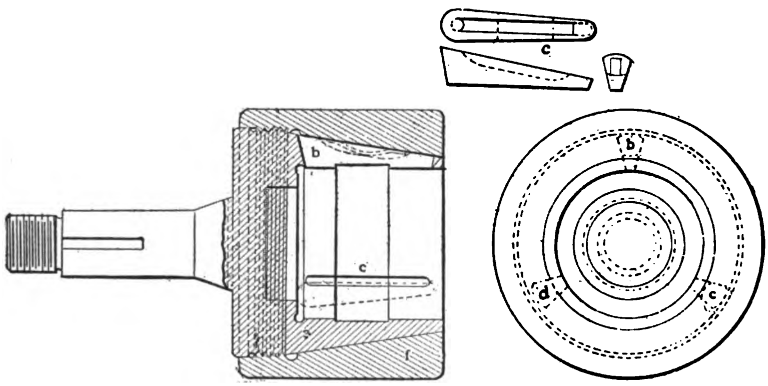


FIG. 40. — Grinding Chuck.

latter cannot drop through, and the latter are of a thickness such that the outside taper sleeve *f*, when screwed home, will pinch the jaws sufficiently to drive the work — the pinching being, however, very slight, as the work to be done is of the lightest and most delicate character. The outer sleeve *f* is a loose fit on the threads at the rear end of the chuck, to insure equal binding of all the jaws. Light springs are attached to the jaws to insure their withdrawal on loosening the grip, and so prevent the top one from dropping down in the way of the next bush to be inserted.

The chuck-carrying spindle revolves within a quill which is held in the quill rest, and which may be removed from the head by opening the latch top plainly seen in Fig. 39. The machines shown in Fig. 39 are always used in pairs, each one of a pair being

set for one of the angles of the bush. On completion of the first angle the latch is opened and the work with both quills is transferred to the second machine, where the second angle is ground.

The work-driving belt is at the left of Fig. 39, and it will be seen that the belt pulley is mounted on a spindle of its own carried in bearings which are in a special casting. This pulley spindle drives the work-carrying spindle by a dog, not shown; the purpose of the arrangement being to avoid the deflection of the work due to the pull of the belt, which would result were the belt pulley mounted on the chuck spindle.

Grinding Collet Seats

The grinding of the collet seat in the spindle is done with the spindle revolving in its own bearings. The swiveled baseplate of the grinding machine is fitted to take the lathe headstock in place of the quill rest shown in Fig. 39; the center hight of the headstock and fixture being the same, and the base fits being interchangeable.

It will be understood, of course, that the grinding machine has the usual characteristic movements of such machines. The cross adjustment for the cut is by the nurled head seen at the left. The lengthwise positioning of the wheel for the work is effected by adjusting the grinding head along the piece on which it is mounted, and the reciprocation of the wheel over the work is effected by the reciprocation of this piece on the box base of the machine — the belt at the extreme right driving the mechanism which effects this movement.

Using the "Diamond Wheels"

The greatest point of interest connected with this work lies, however, in the grinding wheels employed. It is found to be quite impossible to do interior grinding of the standard of accuracy set for this work by means of emery wheels. Such wheels will not correct the surfaces, but ride over the hills and sink into the valleys, leaving the work smoother, of course, but little better, as regards truth, than before. This action is considered to be due to the comparative dulness of the emery wheel, in consequence of which considerable pressure against the work is neces-

sary to make the wheels cut. With outside grinding, this has little effect. The wheel is carried in a firm support, and its mass and inertia help to prevent the wheel from following the surface in the manner described. In interior grinding, the situation is, however, entirely different. The wheel for this work is necessarily carried on slender spindles of considerable overhang. These conditions are all favorable to yielding by the wheel and its supports when pressure is applied, and the pressure necessary to make an

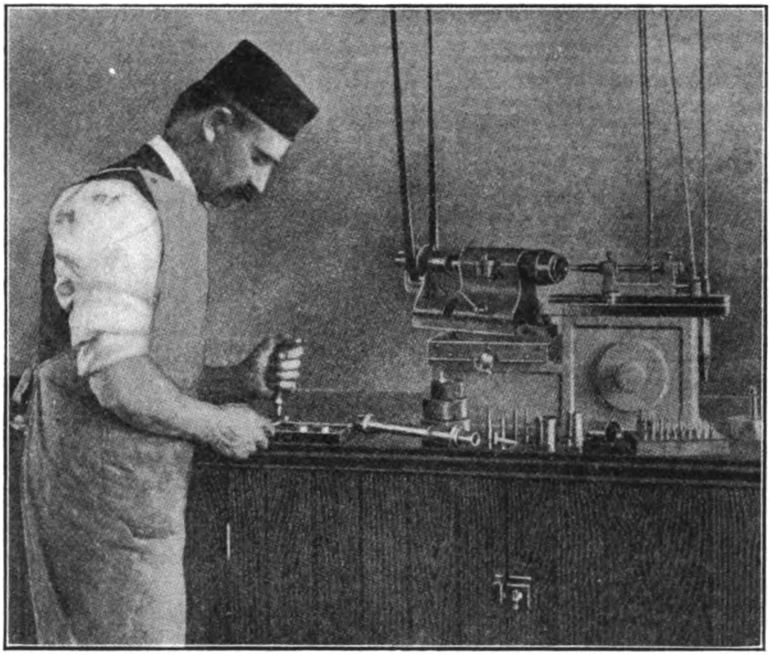


FIG. 41. — Charging "Diamond Wheels."

emery wheel take hold is so great as to make really good work impossible. Emery wheels are therefore used for roughing only, and with holes of less than ¼-inch diameter are not used at all.

Charging the "Diamond Wheels"

To meet these conditions, steel wheels or disks charged with diamond dust are used. These disks are called "diamond laps,"

although they are not used in a manner at all suggestive of what is commonly called lapping. They are used exactly as emery wheels are used, and a better, or at any rate a more descriptive, name for them would be "diamond wheels." These laps are all small, the largest being about ⅜ inch thick, while the diameter of the smallest runs down to .020 inch. The speed at which they are run is of course very high. These laps have already been shown in Fig. 39, and the method of charging them is shown in

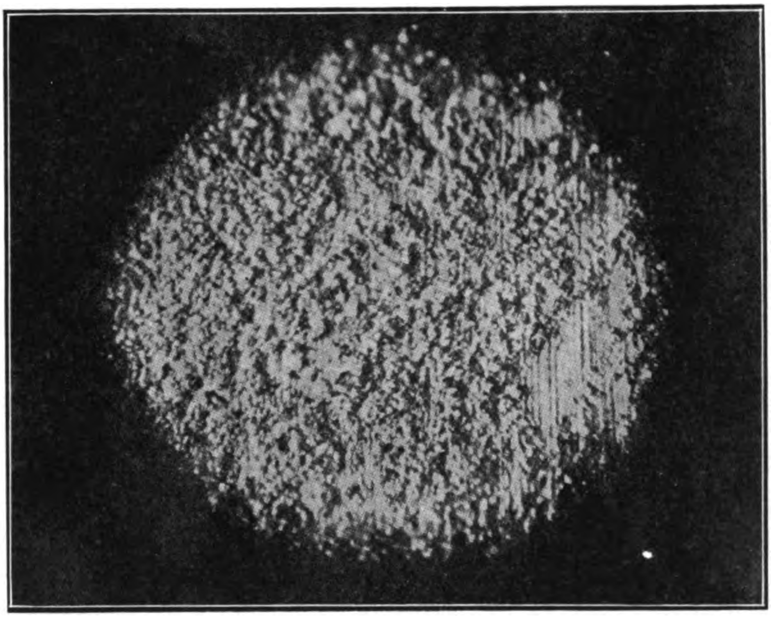


FIG. 42. — Diamond-charged Lap Greatly Magnified.

Fig. 41. The material of the body of the disks is annealed tool steel.

A hardened steel plate having a well at one end will be seen on the bench, Fig. 41. The well contains the diamond dust mixed with oil. This mixture is spread upon the plate, and the workman, holding the spindle of the lap disk in the fingers of one hand and holding a T-shaped hardened-steel tool in the other, rolls the disk between the tool and the block in the manner plainly seen in the illustrations. The pressure employed is not

at all high — no more than can be comfortably exerted by the hand, but it is sufficient to imbed the diamond particles in the steel. Another method, though one that is not much used, employs a small jeweler's hammer, the disk being slowly rolled in the diamond dust and oil, while light taps are given it by the hammer.

Under the conditions of interior grinding described, the work done by these diamond laps is probably as much superior to that possible by an emery wheel as the work of the latter is superior to lathe work. Bearings which have run together long enough to show the character of the fit exhibit a contact which can only be compared to that of finely scraped surfaces, while in appearance the surface is that of a highly polished or burnished piece of steel — the effect being mirror-like.

As these tools are but little known to mechanics in general, samples obtained from the Pratt & Whitney Co. have been photographed. Under a microscope these tools are beautiful objects, the particles being brilliantly transparent. It is, of course, impossible to reproduce this appearance in a half-tone print, but in Fig. 42 illustrations will be found interesting nevertheless. The roundness of the surface makes it impossible to sharply focus more than a small portion of it, and the print will be seen to be blurred at top and bottom. At various places where the diamond particles are scattered the tool marks on the disk may be seen.

Wax for Holding Work on Grinder

Almost every mechanic knows the difficulty of holding small pieces, without seriously springing them, while they are being machined. The ordinary machine vise is all right for work that is large enough to have some strength, but even then great care must be taken in order to work the sides parallel, or two sides square, as the case may be.

At the factory which we have in mind, there is a large quantity of small work, and of great variety, ground on Brown & Sharpe surface grinders, and as it is nearly all hardened, and therefore somewhat crooked, when it comes to the machines, there was considerable difficulty in holding it without having a side or place that was ground spring all out of shape as soon as

the clamps that held it were released. That, of course, made it necessary to frequently change from one side to the other, and raised the cost in proportion.

Some time ago it occurred to us to lay the work down on the platen, perfectly free, and then pour hot wax around it, and after several trials to find the proper wax, it was generally adopted; for winter use about three parts of common beeswax to two parts of rosin. It will be necessary to use a slightly greater proportion of rosin for summer.

This wax is used almost entirely for grinding parallel work. It holds very firmly, the work rarely if ever coming loose; and as benzine cuts the wax off from the pieces after they come from the machine, and from the machine platen, it is very little trouble. A pan of benzine is kept at hand to soak the pieces in. The wax will also hold work sufficiently strong on a planing machine

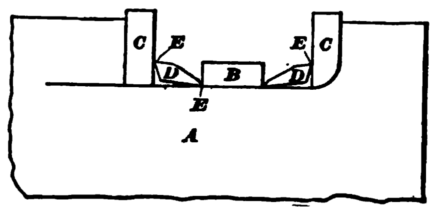


FIG. 43. — Holding Work for Grinding.

or lathe face plate if the cuts are light, and it has the advantage of turning out the work as true as the machine itself, and not depending on vises or fixtures which may not be in the best shape.

Work may be held very well and with good results as shown in Fig. 43, in which *A* is the vise and *B* the work which is held between the jaws *C C* by the strips or ribs *D D*, bearing at the points *E E E E* and tending to hold the work firmly on the base of the vise or fixture. This method has been in use a good many years; but the wax has the advantage of a clear surface over the work, however thin it may be, which prevents any liability of running the tool or emery wheel into the holding device.

Another very important point is that, when there are a number of pieces to be worked all alike, they may all be put on the platen at the same time, or at least it may be covered with the pieces with only a small space between for wax. It is only

necessary to take one off occasionally to caliper, and it may be put on again without trouble. Oftentimes the work is of such nature that it may be put over a T-slot, and so may be measured without removing it from its place. Frequently a block, Fig. 44, is used to hold the work, which also admits of measurements without removing the work from its place, the slot *a* being large enough to admit the base or anvil of a micrometer caliper.

The wax method has long been used by instrument makers on the face plates of small lathes, but its application to the grinding machines is somewhat new.

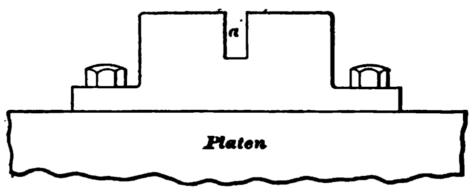


FIG. 44. — Block for Holding Work.

A convenient thing for holding the wax and heating it in is an ordinary pressed tin cup with a spout put in the side. A piece of cotton string laid in the V of the spout, and hanging outside about ¼ inch, will prevent the wax from running down

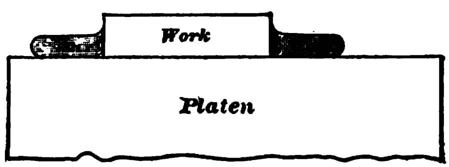


FIG. 45. — Holding Work with Wax.

the outside in the cup, and will enable the operator to direct the drops in exactly the right spot. If the cup is held about 3 inches above the work, the wax will come up pretty high at the edge where it falls, as shown at Fig. 45, as is best where the size of the work will admit; but for very thin pieces the cup must be held up 12 or 14 inches, when the wax will flatten out as it strikes the platen, and will not stand up above the work and have to be pared down, as it would if the cup were not so held. An ordinary gas jet burning up about ½ inch will keep the wax at about the proper temperature all the time.

Polishing and Grinding

A leather or canvas strap coated with emery and running on two pulleys usually of the same diameter furnishes the means for polishing many things which could not be done very well, if at all, on the ordinary wheel. When a strap is used the wheels are generally so placed that the belt travels in a horizontal line; the driven pulley being adjustable to and from the driver, a proper tension can be maintained on the strap at all times. Now, although this arrangement permits of a wide and extended use of the strap, there is one class of work which requires a slightly different arrangement of the parts, to the end that the operator

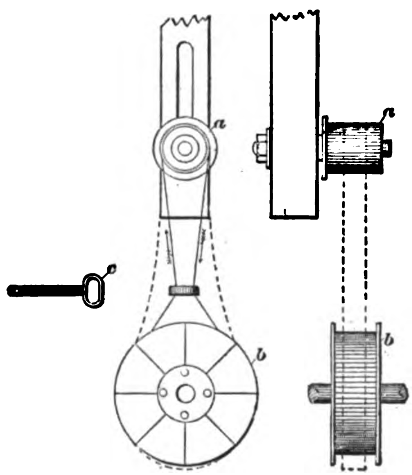


Fig. 46. — Polishing and Grinding.

may be enabled to use the strap to better advantage — we refer to the polishing of the inside portions of handles like *c*, Fig. 46, or like forms. Such work may, of course, be polished by means of a round stick coated with emery, and small enough to pass through the piece, the stick being revolved at a high rate of speed. This method, however, will be found slow and unsatisfactory when compared with the strap when properly handled. In the following we give a description of a polishing frame, which, with a few additions, may be used to good advantage in connection with the strap. By referring to the sketch it will be seen that the arbor upon which the small pulley *a* runs is fastened to a timber

through which a slot is cut in order to permit of a vertical adjustment of the pulley *a*, which should be directly over the pulley *b* and in line with it. The timber itself should be firmly secured to the ceiling above, and made rigid by means of guy rods or braces. The pulley *a* is shown with a flange, to prevent the strap from running off against the timber. The flanged pulley *b* may be constructed on the same general plan as given for the emery wheels, but in addition *b* should have a flange on each side, as shown. The strap being loose when on *a* and *b* as shown in the dotted lines, it will not be driven by the pulley *b*, but if we remove it from *a* and pass it through the handle *c* and onto *a* again, we can then tighten the strap on the pulleys, simply moving the piece *c* down toward *b* until there is sufficient friction on the latter to cause the strap to travel around the pulley *a*. Then by moving the piece around in different directions we are able to polish over half of the desired surface before reversing the piece *c*. The speed in feet per minute at which the strap should travel should not be less than that used for wheels. It will be found more profitable as a rule to purchase the straps from a dealer, as they will give better satisfaction than the home-made article, unless the maker has had experience in that line. When a strap shows any sign of giving out, do not wait for it to end its career while running, for a broken strap stingeth like an adder and biteth like a serpent.

Speed of Grindstones

As the grindstone often plays an important part in connection with the polishing business, it may be well to give some idea of the speed at which they are run in places where the users are supposed to get as much as possible out of them. James Halligan, superintendent of the Lamson & Goodnow Cutlery Company, states that they use stones of 62 to 66 inches diameter, and 7 to 8 inch face. The Lake Huron stones are run 4337 feet per minute, and the soft stones 3650 feet per minute. In the case of the Lake Huron stones the above figure has been exceeded — in a number of cases the rate was slightly over 5000 feet per minute. It would be a difficult matter to determine the highest rate of speed at which a stone could be run with safety, on account of the difference often found between stones from the same quarry,

also because of the liability of hidden defects. A great many grinders test new stones by running them after they have been trued up at a higher speed than the normal one used, taking care to keep well out of the line of fire in case the stone should decide to dissolve partnership with the arbor. If no defects, however, are shown by this test, the speed is reduced to the regular rate, and the stone put into service after it is hacked. The hack somewhat resembles an adze, the blade, however, being much longer, and the handle shorter. The face should be a little more than half the width of the stone; holding the hack at a slight angle to the stone, cut around on one half of the face of the stone, then, changing the angle of the hack, finish the other half, the cuts being made about 1½ inches apart. As the stone wears away this operation must be repeated as often as needed, and if it is out of true the high spots should be hacked closer. By a little practice and judgment the stone can be kept true by means of the hack alone.

The question as to how a stone should be hacked will be answered best by the stone itself, especially if the operator is on piece-work; for a smooth stone seems to have no cutting qualities at all in comparison with one freshly hacked.

Although solid emery wheels are making rapid strides, the hacked grindstone running in the neighborhood of 5000 feet per minute is not quite out of the race yet.

SECTION II

LAPS AND LAPPING; CONSTRUCTION AND USE OF TOOLS AND PROCESSES FOR FINISHING GAGES, TOOLS, DIES AND MACHINE PARTS TO ACCURATE DIMENSIONS.

Requirements for Lapping

A lap is a tool composed of copper, brass, lead or other soft metal, and sometimes of wood. It is usually a rotating disk or plug. It is used as a conveying agent in applying a cutting or polishing powder of emery, diamond dust or other suitable abrasive, in the cutting of gems and glass, the polishing of cutlery and in the reducing of hardened steel and machined cast iron surfaces to accurate dimensions.

Now, while it is of the utmost importance that the mechanic understand thoroughly the manipulation of machine tools; that he be familiar with approved processes, methods and means for machining steel and iron, and also that he possess sufficient skill to work very accurately with metal-cutting tools, there are also other processes which he must have a good working knowledge of in order to construct perfect gages, and measuring instruments, or to reduce machine parts and tools of precision to accurate dimensions.

He should have a knowledge of hardening and tempering, understand the action of high carbon steels under heat treatment, and know the most approved methods for quenching steel after the heat treatment. Of this we treat fully in Section IV.

The most important process necessary to the production of work as accurate as that referred to above is that of lapping, for upon this depends the efficiency and longevity of the tool or part. If the lapping is not properly done, all work that has gone before — no matter how accurately and carefully accomplished — will

go for naught. Therefore a knowledge of this process, possession of skill in the use of the tools, and a comprehension of the variety of designs of laps and their adaptability for work of different classes and various shapes, are absolutely essential to the gage maker, the tool maker and the constructor of precision machinery.

In the following pages are taken up the most approved lapping processes, together with the design, construction and use of laps employed in various grinding departments of up-to-date shops. The methods and designs treated represent the most advanced practice.

Laps

Laps — judging from what we have seen — seem to be among the tools in the machine shop that are pretty generally neglected, except in shops where so much use is made of them that they are an actual necessity. There are few machine shops in which laps of some form, at some time or other, are not used, and if a set were kept in the average shop, a satisfactory use would be made of them.

We have proved this several times, on jobs where the lapping of holes and spindles or plugs was a large part of the work, and where, after a good stock of laps had accumulated, we were continually being asked by different workmen who had pieces requiring to be lapped, if we had this or that size of lap.

A man would come to the bench with a careworn and anxious expression upon his face, and in his hand, perhaps, a cutter just hardened or a piece with a hole in it he had bored in the lathe as near as he could to the required size. It seemed to be all right in the chuck or upon the face plate, but come to get it upon the bench it was a little tight; or if a cutter, in hardening the hole which at first was right, now is a little out of round; perhaps he has left it small and ground it out in the universal grinder, and, as with the lathe job, it wants "just a hair" taken out of it. The lathe job cannot be chucked again or the cutter go back into the grinder. We speak of these cases merely as examples, and not as embracing, even in a small measure, the uses for laps in the shop. Workmen accustomed to using them know their value and the many occasions upon which they can be used to advantage.

Our shopmate looks at our row of laps and says, "Say, Joe, got a $1\frac{1}{8}$-inch lap? This thing is just a shade small."

We pick out a 1⅛-inch lap, push a mandrel into it, and hand it to him. A great change comes over our friend's face. He smiles now. "Oh," he says, "that'll just do it." He knows how to do the rest, and in a few moments is back again with the lap and mandrel, and very well disposed toward us both — the lap and myself.

Now, if there is no set of laps, you will see him down upon the floor, pawing over a box at the end of somebody's lathe, or under the bench, rattling around among a miscellaneous collection of chunks of cast iron, brass, copper, lead, etc. The gloomy look gets gloomier, and he talks rather forcibly about there being everything there but what he wants. He has finally to take something larger and turn it down.

When it will just enter the piece he wishes to lap, he files it a little on the end, puts on some oil, and scatters a lot of emery all over the lathe, so as to be sure and get some on the lap, and tries to crowd his cutter, or whatever it may be, on. Of course it sticks and gets hot, and so does he. More oil and emery, and by and by it slips onto the place he has turned upon the lap; but there was rather more to come out than he reckoned for, and if he is in luck he will have room to turn another spot for a lap; if too short, then he must hunt another chunk. This form of lap is what we call the solid-chunk lap, and is one of the meanest we know of.

We have seen them made of wood and sawed in the end for three or four inches of their length, with a wedge in the saw slit at the end for adjustment. This makes a lap some like a policeman's club — biggest at one end. Those who have tried this form will appreciate the beauty of this method of adjustment.

The idea seems to be quite generally entertained that a lapped hole must be right; but the fact that a hole is lapped is no guarantee of its perfection.

The "S. C." lap is made of almost anything that comes handy — cast iron, wrought iron, machine steel, brass, copper or wood, and if any one of them in this form of lap will make a straight hole, it is news to us.

Lead Laps and Cast-Iron Laps

Then there are lead laps, and, in fact, many think laps must be made of lead. This type is more generally used in machine

shops. In speaking of laps many understand you to mean lead ones, as though there were no others. They have been used for years in gun barrels and nothing better seems to have been found, but for a set of laps for a machine shop to be arranged in sizes to conform to the reamers and mandrels in use we are decidedly of the opinion that soft cast iron is the best material to use.

We do not wish to be understood as saying that good holes or spindles cannot be made by lead, as it is used in some forms of laps to good advantage, but we think for the use we have in mind cast iron is better.

First, perhaps it will be well to state some of the difficulties encountered in the use of lead laps and compare them with cast iron. Lead laps are made in several ways. The most common, probably, is to cast them into a mold around a taper mandrel with a groove running its entire length, into which the lead flows and prevents the lap slipping. The mandrel is put into an iron or wood mold usually made in halves. At each end for a short distance the mold fits the mandrel or is made to by inserting a narrow ring. This holds the mandrel central in the mold and retains the lead. When the lead is cool the mold is opened and the lap turned to size on the mandrel.

Among the faults which have been found with lead laps for lapping holes is their liability to lose their form. Experience has taught that a lap will produce better results if it is kept as near to an even diameter its entire length as possible. Good results cannot be gotten from laps that are "off" in this respect. They should be kept as near straight while using as possible, by reversing the piece to be lapped on inside work, and by reversing the lap on outside work as often as convenient, and if the lap is still uneven it should be made right by turning, grinding or filing. We have found it much harder to keep a lead lap of even diameter than a cast-iron one, and for these reasons we slit a cast-iron lap and usually a lead one. When the lead lap is enlarged by forcing the taper mandrel through it, there are times when it does not respond to a light tap and is given one a little harder. It takes some more force to start a mandrel on a lap than it does to keep it going, as in most cases with things that move, and the mandrel sometimes goes too far; then it has to be driven back and perhaps out, the lap shut up and the mandrel again adjusted or the lap reduced by filing or turning. A cast-iron lap has sufficient elas-

ticity to close on the mandrel when it is forced back, and that is all that it is necessary to do to reduce the size of the lap.

Lead laps enlarge most, as the taper mandrel is forced into them to increase the diameter at the back end where the mandrel is largest and the lap consequently thinnest. This fault is not nearly so apparent in cast-iron laps.

To insure, as far as possible, the even enlargement of laps, either cast-iron or lead, the mandrel should fit the lap its entire length. If it does not, it will stretch the lap most at the places where it fits.

After the lap is fitted to the hole to be lapped the addition of the cutting material — usually emery — as it imbeds itself in the lap will enlarge it enough to cause it to cut as much as it should, and as it enlarges the hole the lap is removed, wiped and adjusted again. Laps quite often are run too fast. Better results can be obtained at a moderate speed; the work does not get so warm, and it is thought that the laps cut faster; the emery stays upon the laps better and does not fly off. A lead lap must usually be held in the hand while the mandrel is being rapped through it. If it rests upon its end upon a block while being rapped it is apt to swell or get pinched at that end. A cast-iron one can be rested in this way without injury or can be put in a mandrel press and adjusted in that way.

Equipment for Making Laps

The tools necessary for lead laps usually are a ladle, some molds and taper mandrels. Iron molds are all right, but wooden ones used by some soon char out and become useless. For a set of cast-iron laps a few tools are necessary. They are not very expensive and when once made seldom or never have to be replaced.

Six taper mandrels, Fig. 47, reamers and reamer drills are all that are actually necessary for a set of laps to be used in connection with the usual sizes of reamers and mandrels from ¼ inch to 3 inches diameter. Some additional rigs that have been made from time to time, and that have been found convenient in lapping generally, will be spoken of later.

A handy form in which to have cast iron for hole laps is in round pieces of different diameters, 18 or 20 inches long. The laps can be cut from them, chucked, drilled and reamed.

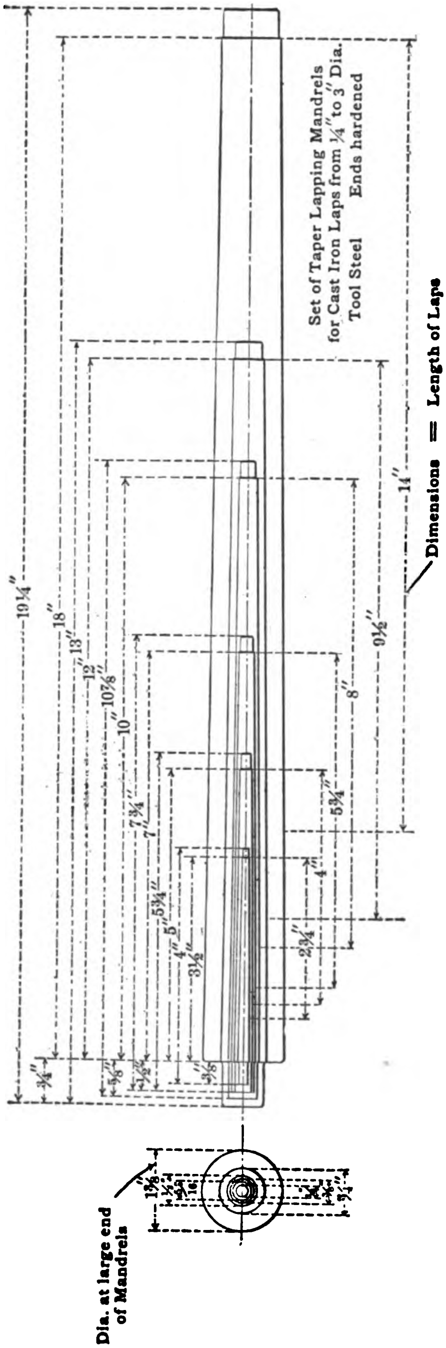


FIG. 47. — Taper Mandrels for Lead Laps.

From 1/4-inch to 1/2-inch diameter we use copper or brass; from 1/2-inch up, cast iron. We make the laps for holes as long as we can conveniently make the taper reamer. Fig. 47 shows a set of taper mandrels for laps from 1/4-inch to 3 inches diameter. The smallest takes laps of 1/4 and 5/16 inch diameter, and the others in regular order, 3/8 to 9/16, 9/16 to 1 3/8, 1 3/8 to 1 5/8, 1 5/8 to 2, 2 to 3 inches. This number (six) is probably the smallest that should be used, and two or three more would be better.

Taper Reamers for Laps

In connection with taper reamers for laps, perhaps it may be well to speak of the difficulties in making them. They are necessarily long and slim, and difficult to harden without springing, and although to men accustomed to making them there may be nothing new in what follows, it may be of some assistance to those who are not familiar with the work. In addition to careful heating and cooling, the reamers can be straightened after tempering even if they are quite badly sprung. Cool them first in cold water and then in lard oil, leaving them in the water an instant until the red disappears; then finish cooling in oil; this leaves a softer core of metal in the reamer and the latter is more easily straightened. Turn up an emery wheel to fit the flutes and grind them out; this smooths the front face of the tooth, and gives it a much keener edge when the top is ground. After drawing the reamer may be placed in the lathe on an old pair of centers shaped up and hardened and kept for such jobs, with a piece of hard wood in the tool post. Warm up the reamer with an alcohol lamp or Bunsen burner as hot as possible without starting the color; bring the wood against the high side of the reamer with the cross feed screw, and spring the reamer until it is true enough to grind. The operation will have to be repeated a few times, trying the reamer as one would a shaft, by revolving it with the hand, on the centers, after springing it. The reamer can be ground in the universal grinder, round, as with a taper plug, stoning a clearance by hand afterwards. Previous to this last grinding, the flutes should be again polished out. The first grinding in the flutes is to smooth any roughness left in milling and brighten the surface sufficiently to color in drawing. The second time more attention is paid to smoothing up the face of the tooth

for an edge. The taper mandrels are made of tool steel, with the ends hardened previous to taking the finishing cut in the ordinary manner.

The drills are long twist drills, and if they cannot be cut in the shop, an ordinary drill may be spliced by turning a short shoulder on its shank and fitting it into a piece long enough for the lap, then soldering it in.

Chuck for Holding Mandrel and Lap

Figure 48 shows a handy chuck for holding the mandrel and lap. Make several sizes of bushings to go with the chuck, with

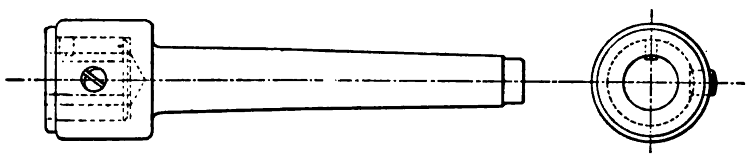


Fig. 48. — Chuck for Mandrel and Lap.

different sized holes in them to fit the different mandrels, one chuck in this way answering for all sizes of mandrels. A screw or pin goes through the bush, whose point just clears the flat spot

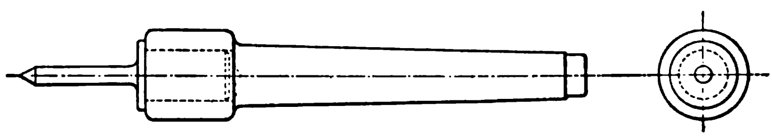


Fig. 49. — Center Held in Taper Shank Collet.

on the end of the mandrel, preventing it from turning in the bushing. The mandrel and lap can be taken out by simply drawing back the tailstock spindle and pulling the mandrel from the chuck. A center held in a taper shank collet, as shown in Fig. 49, in the tailstock is handy for inside or outside lapping. It is long enough in one case to run the piece being lapped off upon it, to remove the lap from the lathe, and in the other the lap can be run off upon it to remove the piece from the lathe.

From the emery and oil that works into the center at this end of the mandrel, the center wears considerably, and this is a handy form to repoint and lasts a long time, also it is easier to make than the common center. Two or three sizes can be used to

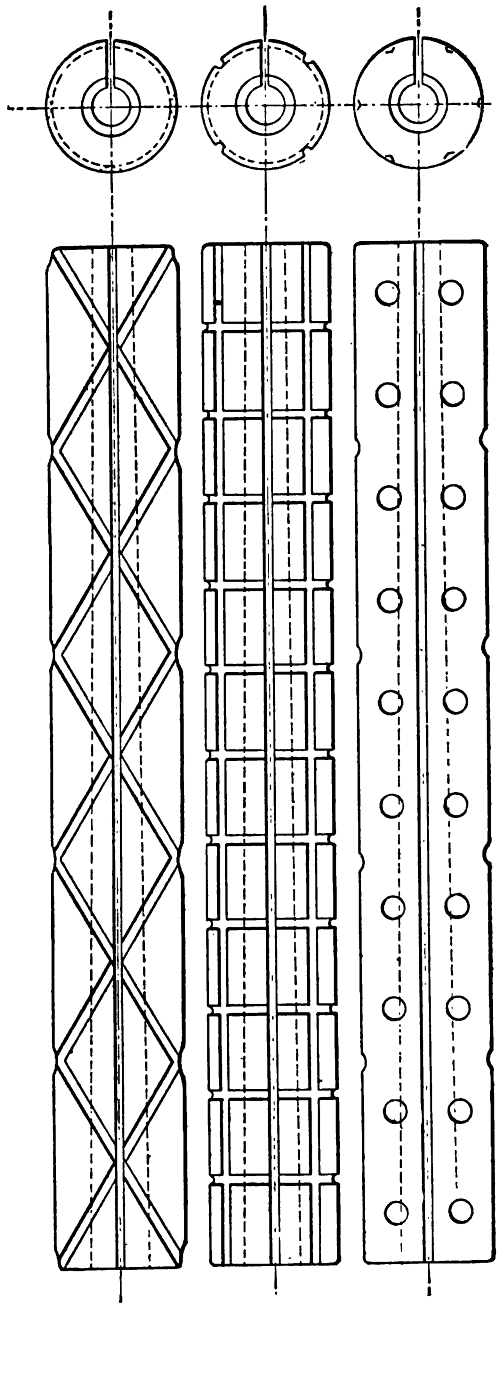


FIG. 50. — Ways of Scoring Laps.

advantage. With the tools shown, cast-iron laps can be made by any boy who has survived two years in a machine shop, with the usual attention from the foreman.

Scoring Laps

Figure 50 shows three ways of scoring laps. The spiral can be done in the milling machine, or it can be done well enough with a drill file in the vise. The straight form can be made in the lathe entirely, or the lengthwise scores can be cut in the miller. The drill-spotted lap is center-punched, and then spotted at the drill press in a V-block going down just to the corner of the lip of the drill. Either of these forms works well, and can be used as found expedient. Laps of ½ inch and under need not be scored. A key or feather is not needed in the mandrel, as the

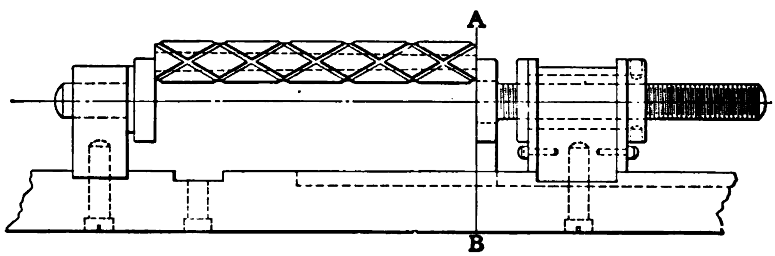


Fig. 51. — Lap Holder for Milling Vise.

laps never turn, except perhaps in cases of laps of small diameter that are quite thin. A satisfactory taper for reamers and mandrels is ¼ inch per foot.

Set of Laps for Holes

In many cases a set of laps for holes might be all that was needed, and very likely would soon prove their value. The laps are not very convenient to hold while slitting them with the ordinary means. Some hold them on the bed of the milling machine with two straps having a round nose forged at one end to enter the hole in the lap, resting the lap in the T-slot of the bed or in a V-block. Fig. 51 shows a holder that will take any lap and can be placed in the milling vise. The work will not cramp the cutter held in this way by its ends. If the laps are slit

on the mandrel the machine must be set to the taper of the mandrel, and if one cuts through the lap he marks the mandrel. It is an easy rig to make and set.

Mandrel Press for Laps

If the laps are enlarged by rapping the mandrels into them, a block like Fig. 52, for the end of the lap to rest on while rapping, is handy, or a mandrel press like Fig. 53, which can be held by its lower jaw in the vise in an upright position, or by one of the side bars in a horizontal position — or in still another way by fasten-

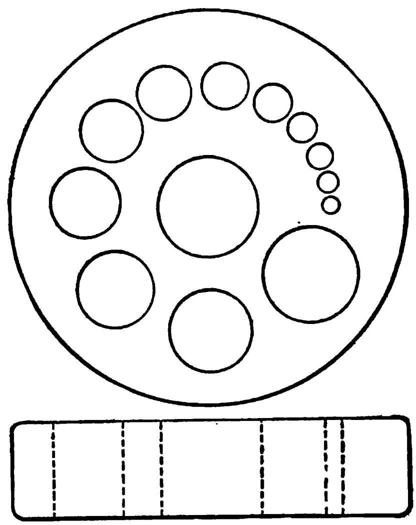


Fig. 52. — Block for Resting End of Lap.

ing a plank upon the bench so it will project enough beyond to allow the side bars to drop through two holes cut in the plank.

Figure 53 shows the construction of this press. The necked side bars are 1½ inches square, of machine steel left rough, centered and nicked in. The right-hand one has the corners turned off slightly to allow the anvil shown in section to turn on it. It is held in place by the hickory wedge shown at *a*.

The follower is made of sheet steel — the sides about $\frac{3}{64}$ inch thick and the connecting piece ⅛ of an inch thick. That portion of the sides above and below the saw slits is bent at a little sharper angle than a right angle to grip the side bars a little, causing

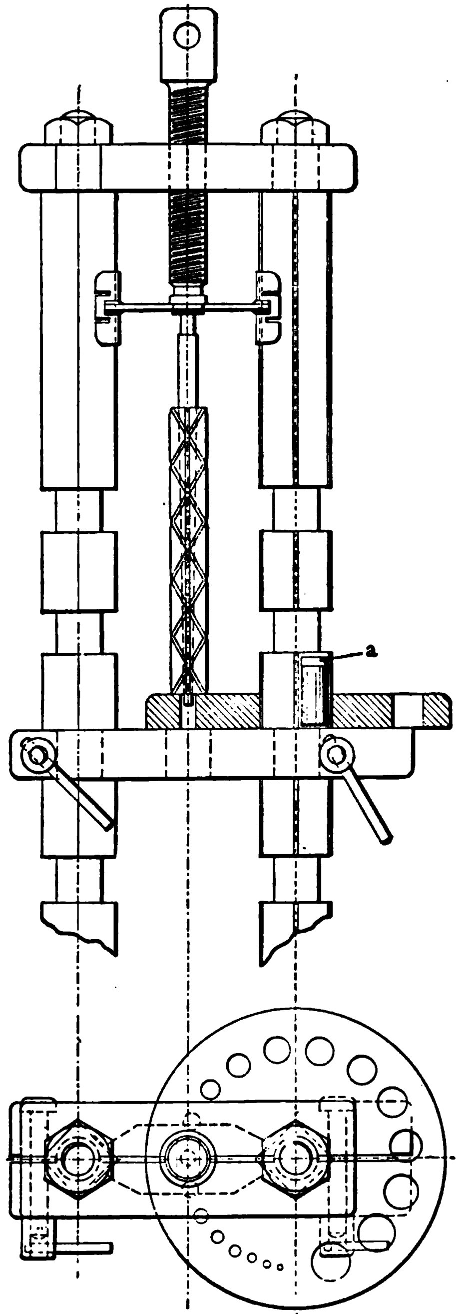


FIG. 53. — Mandrel Press for Laps.

sufficient friction to hold the piece wherever it is moved. The ends of the pieces should also be turned out a little so the edges will not catch upon the side bars when moved up or down them. A screw is preferred to a rack, as it is easier to get a very slight movement of the mandrel when it is needed.

Forms of Laps for Outside Work

Figure 54 shows different forms of laps for outside work. Lead in this form of lap does very well, as it is protected by the casting into which it is poured, but even here cast iron may do just as well. No. 1, Fig. 54, shows a lap casting recessed and filled with lead. The retaining lips in the casting are dovetailed a little to hold the lead, and a few holes are drilled in the casting for the same purpose. The lead is run in at the bell-mouth hole at the top. By making the recessing in this form of lap shallower, sheet brass, copper or lead can be forced into it for laps over 1 inch diameter. The sheet metal can be curved some, as it is bent so it will spread out into the dovetail when forced in. A piece of round stock some smaller than the size to be lapped can be used to force them in place. Get the sheet metal wrapped in place as well as possible, then by putting the round piece in the lap and the whole between the jaws of a vise the sheet metal can be forced into place. Copper, or brass, should be annealed before putting it into the lap, which may need a little touching up with a scraper or file to bring it to a good bearing on the work to be lapped, after the lapping pieces are in place. In connection with the outside laps it may be well to mention a use for them not generally understood — their use upon reamers. One form of reamer has been used quite largely and very successfully.

Laps Used upon Reamers

The flutes were milled sharp — without land. The reamers were hardened, the flutes ground out and then the reamers were ground in the universal grinder cylindrical — just as straight work would be, and left about .002 over size, to which they were reduced by lapping with a lap shown in No. 2, Fig. 54. This lap is adjustable and the slit is at such an angle that the teeth of the reamer running backwards do not fall into it. A piece of wood

is sometimes put in the slit if the reamer runs at all rough, but this is hardly ever necessary. The reamer comes down to size quite rapidly in lapping, as the surface to be lapped is quite limited. Cutting the reamer sharp with no lands on the teeth, after grinding in the universal, leaves just about enough land, although this can be regulated if too much stock has been left in diameter by grinding with an emery wheel on the front face of the teeth and cutting the lands down as much as desired. All reamer makers pay particular attention to this face of the reamer tooth, and very many machinists making reamers in the shop pay none at all to it, except, perhaps, to stone it a little.

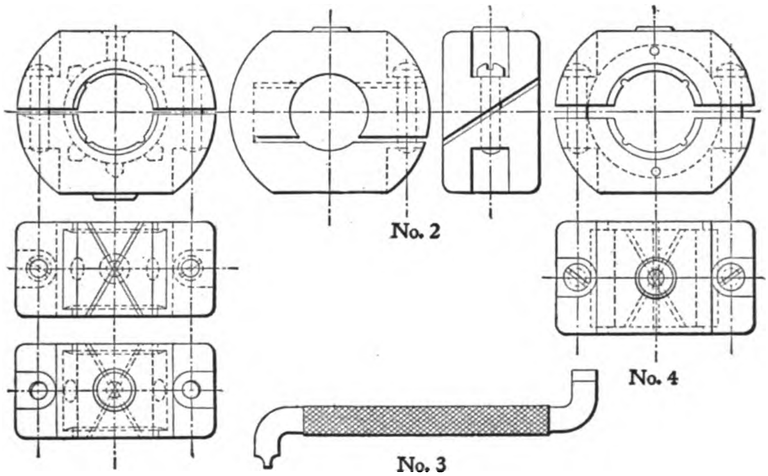


FIG. 54. — Different Forms of Laps for Outside Work.

MATERIAL FOR OUTSIDE LAPS

For sizes of outside laps up to 1-inch diameter flat bars of cast iron from 18 to 24 inches long, of proper widths and thickness, can be used. They are cleaned up all over on the planer and cut off as needed. For larger sized castings of the form shown at No. 1, Fig. 54, the casting is in one piece, a hole cored in it. The screw holes for the adjustment are drilled and tapped, it is then placed on a face plate, the hole bored and sawed in halves in the milling machine. The boss on one side is for marking the size, and is high enough to allow for two or three removals as the laps

wear and are rebored to other sizes. There is not finish on them, the spots where the screw heads rest being swept off with a counter bore.

Lapping Screws and Nuts

These forms of outside and inside laps are useful to lap screws and nuts. A nut, sometimes, made for a gage when hardened will close up a little, and can be lapped to size in a few minutes by cutting the proper thread upon an inside lap. A screw can be treated in the same way. Long screws, if they show some slight unevenness that causes the nut to run hard or bind, can be reduced very easily by lapping and made to run uniformly. The halves of the lap must be kept parallel by the adjustment screws, or the lap will come on the thread and bind. In fact, for either screws or straight-wound work, it is well to be careful in this respect. It is easy to do this by watching the openings between the halves of the lap, and keeping it of a uniform width with the adjusting screws. For adjusting these screws use a screw-driver, shown at No. 3, Fig. 54.

Frequently for screws over ¾-inch diameter is used a recessed lap, placing the screw in it and pouring lead around it.

Lapping Duplicate Work

For lapping a large number of pieces of the same size, laps made as shown at No. 4, Fig. 54, are a good form. The lapping pieces are simply rings of metal, and can be replaced at small expense. A pin, shown in each half of the lap, holds the lapping pieces in place.

The length of outside laps must vary some, according to the length of the work upon which they are to be used; but for an average length, a lap of ⅜-inch diameter would be ⅝ inch long, 1½ inches diameter 1½ inches long, a 3-inch lap 2½ inches long. If the set could contain two or three of the same size, there should be one of each size about twice these lengths. We seldom use emery coarser than 120, and almost always flour. There is considerable difference in the grades of flour by different makers. For finish lapping use washed emery, and if this cannot be obtained, stir up the flour in the oil, and, after allowing it to settle some, use the top. This is rather uncertain business, as

one is apt to get a few particles of the coarser emery in it, and it is exasperating, after getting a plug finished, to have one of these rocks come swimming along and plow out a canal the length of the plug. For very close and particular work, roughing and finishing laps are used; but generally by washing the lap thoroughly in benzine, one lap can be made to answer.

The tools for making these laps and the laps themselves should be kept on racks similar to those used for reamers and mandrels and convenient to them. A set of laps, that can be got at and used us easily as the shop mandrels and reamers are, seems to be a very good feature.

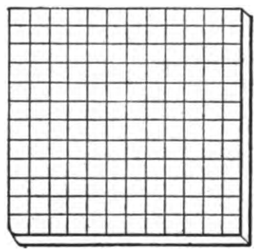


FIG. 55. — Flat Cast Iron Lapping Plate.

PREPARATION OF EMERY FOR USE IN LAPPING

To prepare emery for lapping, accurate tools, gages, punches, dies, etc., fill a half-pint bottle with machine oil and emery of the proper number suitable for the work in hand; the proportions of about 7 parts of oil to 1 part of emery by bulk is right. Mix thoroughly and allow to stand for a half-hour, during which time the heavier particles of emery will settle to the bottom. Now take the bottle and carefully pour off about one-half the contents without disturbing the settlings. The portions poured off contains only the finest emery and will never scratch the work.

APPLYING EMERY FOR SURFACE LAPPING

For surface lapping put some flour emery in a linen bag and tie up closely with a string. Dust out the emery by striking the bag against the surface plate; use turpentine for rough lapping and the dry surface plate for finishing.

Lapping Plate for Keyseat Gages, and Flat Gages

The lap shown in Fig. 55 was a plate of cast iron which was first scraped to a smooth finished surface, after which parallel grooves, $\frac{1}{16}$ inch wide by $\frac{1}{32}$ inch deep, were cut upon the surface, forming small divisions $\frac{3}{8}$ inch square. This plate was charged with fine emery and turpentine, and when used on keyseat gages or other flat pieces was capable of producing a very fine surface.

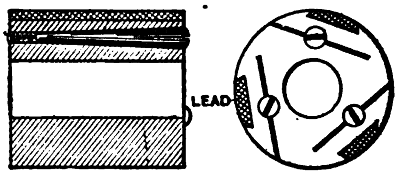


Fig. 56. — Wooden-bodied Lap.

Wooden-bodied Lap for Milling Cutters

Figure 56 shows a lap formed of a smooth turned piece of hard wood, on to each end of which was fitted a ferrule of wrought iron to prevent splitting. A narrow slot was sawed through the center and into this was driven a wooden wedge to compensate for wear. One of these laps would last for a long time and they were used in milling cutters when the amount of stock to be removed from the holes was not sufficient to warrant the use of the grinder. For removing tight spots, etc., this lap is very valuable.

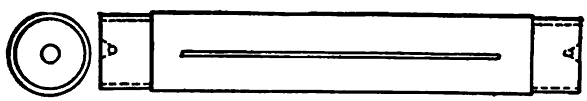


Fig. 57. — Arbor-lap for Ring Gages.

Arbor-lap for Ring Gages

The lap shown in Fig. 57 is a cast-iron cylinder that was bored to fit the arbor with which it was to be used. Three strips of lead were dovetailed across the surface and these carried the charge of emery and turpentine oil. Three small tapered holes were drilled and reamed longitudinally, and tapped at the small end to receive the taper expanding screws. After these were fitted, diagonal slots, which intersected the holes, were cut, so that by a

slight turn of the taper screws the lap could be expanded to adjust it for wear. This lap was used on the inside of ring gages.

Contracting Lap for Plug Gages

For lapping the outside of plug gages the lap shown in Fig. 58 should be used. It consists of a casting bored out to the required size and fitted with three wide strips of lead. A slot cut through the lugs on the upper side and fitted with a pair of set screws was used to form the means of adjustment. A handle was provided to prevent the lap from turning while the plug gage upon which it was being used was revolved in the machine.

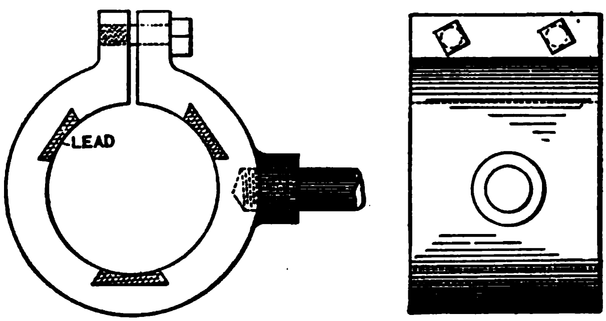


Fig. 58. — Contracting Lap for Plug Gages.

Lap for Worn Micrometer Faces

To lap a pair of micrometers, the faces of which have become considerably worn, procure a small piece of plate glass and place a few drops of oil and flour of emery upon one side; leave the other side of the glass perfectly clean. Then close the micrometers tightly upon the glass, and slide the glass back and forth between the jaws for some time. Then after thoroughly cleaning the first jaw, the glass should be reversed and the process repeated upon the other jaw. In a short time the micrometers, so far as the jaws are concerned, will be as good as new.

Lapping Machine for Thread Gages

The lapping of plug and ring gages is the most important part of the construction of such tools. A screw plug or ring

gage should never be case-hardened; even if it is made of machinery steel and drawn to a blue, it is so brittle that the top of the thread breaks off; even when fitting in lapping it has been known to break off. Lapping is very slow and tedious work when using an engine lathe, by moving the shifter to and fro; for that reason for lapping small thread gages a lapping machine was constructed as shown in Fig. 59. The spindle extends about 5 inches with a left-hand screw *a* on the end. A cross-bar *b* is fastened to the end of the machine with two screws *c c*, two ½-inch holes are drilled through the ends of the cross-bar to fit the two studs *d d* and these are held in position with nuts *e e*. A slot is milled in the end of each stud to fit the lever, and the latter is held at the end with a pin and attached loosely to a half-

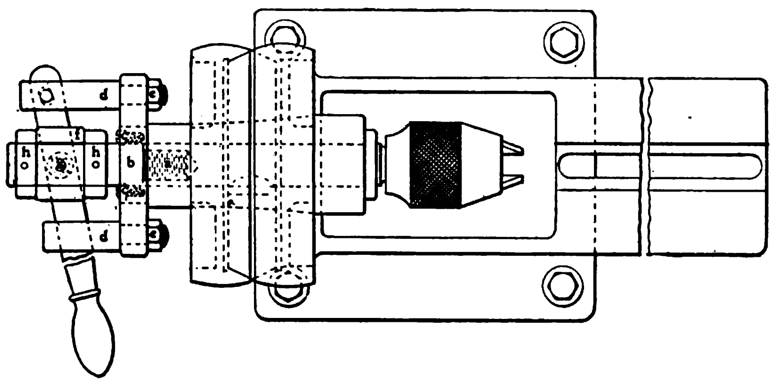


Fig. 59. — Lapping Machine for Plug and Ring Gages.

round box *f* by a screw *g*, the box being mounted freely between collars *h h*. By moving the handle to and fro the spindle is driven right and left. A large drill chuck is used to hold the laps and screw plugs when lapping. With this machine the operator is in a sitting position, with his left arm on the lever and the right hand on his work.

Lapping Gages and the Use of Test Gages for Them

The first thing in lapping is to get the emery in good condition.

Test gages are used in lapping the ring gages, and a tap size plug is shown in Fig. 60. Right here is a little kink: To lap a plug round and straight, after it is ground never lap it across the sur-

face slowly, but draw the lap back and forth an inch to a turn, as indicated by the lines on the plug; by so doing a perfectly straight and round surface is obtained. It will be found that a good many plugs are out of round because the lap has been drawn across the surface too slowly. When within .0001 inch of size, the lap and plug should be cleaned to remove all the emery and only machinery oil used; this will be found to give a very brilliant and shining surface. Another test plug used is shown in Fig. 61. This has only four threads, with a sharp V-bottom, and measures

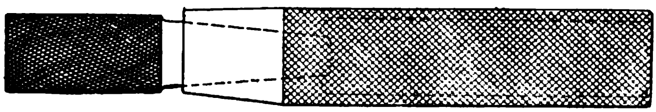


Fig. 60. — Tap Size Plug Lap.

.001 under size on the top or outside diameter, but must be exactly to size measured in the angle of the threads. Still another screw plug is used, with a V-bottom thread, and to measure the right size on top, but .001 under size in the thread angle. Then a screw plug is used that is standard almost everywhere, and should be double the width of the ring gage. By having these test plugs an accurate external thread gage can be made; without them one cannot know where to lap when the gage doesn't come right.

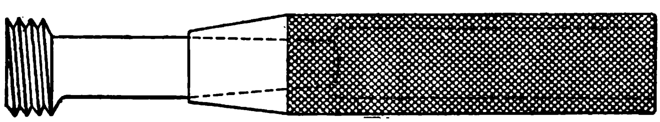


Fig. 61. — Test Plug.

Overcoming Effects of Overlapping

If the ring gage happens to be lapped a trifle over the size, a very practical way to save it is to heat the gage to a light straw color and let it cool slowly; it will then have shrunk sufficiently to allow the straw coating to be lapped off, and sometimes more, saving the gage, providing the lead is right. Sperm oil should be used when fitting thread gages, and not thick, heavy oil, as that is likely to cause false fitting. It has been found when a screw plug and ring fit fairly well in a horizontal position, that if

raised to a perpendicular position they will fit much easier, because the weight of the handle prevents true fitting in a horizontal position.

Sets of Ring-thread Gage Laps: Their Use

When lapping ring-thread gages sets of five laps of machine steel should be used to assure a perfect lead, and these should be cut with the chaser, with .0001 inch difference in the diameters. There should be one straight lap for the top size and one lap with V-bottom, .001 under on top of the thread, but right to size measured in the thread angles; if it is found that the top of the thread in the ring gage is to be lapped, this lap will do it.

Adjustable Lap-holder

An adjustable lap-holder, shown in Fig. 62, is useful. It is made of tool steel, is spring tempered, and has a very thin slot in

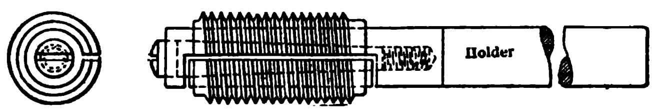


Fig. 62. — Adjustable Lap-holder.

the center and one at each end of the lap cut to the center line. A taper screw in the center gives it a very fine adjustment and obviates hammering on the end of the lap, which upsets the end and sometimes changes the lead of the ring gage.

Stock Allowances for Lapping

A screw plug can be measured all over with the micrometer and wires so that no test gages are required. In hardening such a plug it generally swells from .0002 to .0007 according to the size of the plug, and it will be found that the extreme end swells from .0001 to .0003 more; so when cutting a screw plug .0003 is enough to allow for lapping. But in the ring gage .001 inch should be left for lapping, as both ends open and the center shrinks.

Laps for Screw Plates

Screw plug laps are made in a similar manner to the ring gage laps. Taps are made, one with V-top and flat bottom and to

measure right on the thread sides of the angle, and one tap with "V" or sharp bottom and top, and to measure .0001 under the angle. Five laps are used with a difference of .0002 in diameters. For the top of the threads on the plug a straight lap is used to bring to finish size.

A lap-holder is shown in Fig. 63. This is made of machinery steel nurled on the outside and bored to receive the lap rather freely. Cone-pointed screws hold the lap in place. When lapping large plugs, a short piece of wire screwed into the holder acts as a handle and is found very convenient.

When only the bottom of the thread on the plug is to be lapped, a single thread lap will do the business. This is made of soft

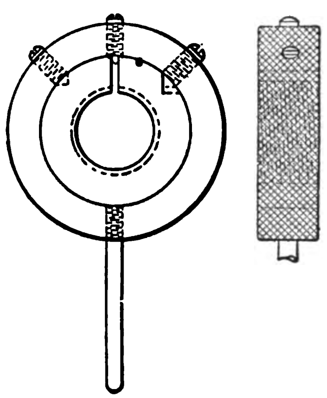


FIG. 63. — Lap for Screw Plates.

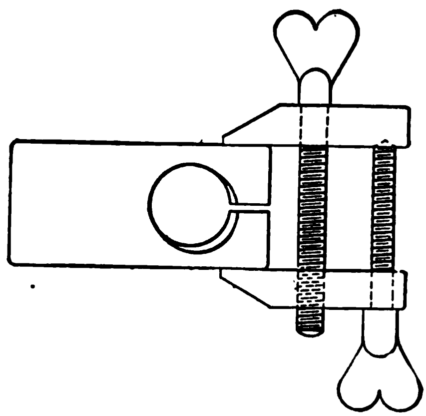


FIG. 64. — Lap for Screw Plates.

metal, the width of thickness of the thread to be lapped, and tapped out the same as an ordinary lap. The sides are scraped off for clearance, and a slot is cut in the front end. The lap is held and adjusted with a light clamp like Fig. 64. This has proved very convenient, as it does not affect the lead, angle or the top of the thread.

Lapping and Brazing Black Diamond Tools

Figure 65 shows a fixture for lapping black diamonds which are used in the forms shown at *B*, and *C*, Fig. 66, for finishing pieces made of brass and vulcanized rubber. The shank of the holder *D* revolves freely in the body *E* for lapping round-nose

diamonds, and the nurled nut *F* clamps it in position for lapping those of angular shapes. The splined collar *G* is graduated in degrees for setting the holder at the required angle. The adjustment for the required degree of clearance is obtained with the nurled and pointed screws *H*. The points of these screws hold the fixture in position on the wooden top of the rotary lapping machine. As will be seen in the illustration, the fixture can be

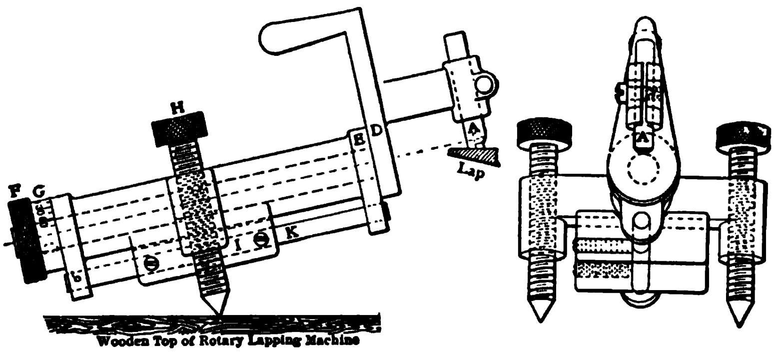


Fig. 65. — Fixture for Lapping Black Diamonds.

adjusted to bring the axis of the holder to lie at various angles with the top of the lap, so that when a round-nose diamond is lapped by rocking the small handle back and forth the shape of the clearance will be a section of a cone. *I* is a movable weight attached and sliding on the rod *K* for applying pressure to suit

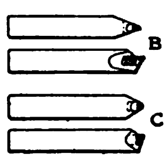


Fig. 66. — Black Diamonds.

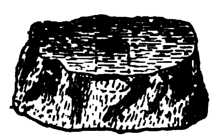


Fig. 67. — Crucible for Brazing Diamonds.

the various sizes and shapes of diamonds. Fig. 67 shows a crucible for brazing the diamonds into the bessemer steel shanks. It is made from a remnant of a wornout crucible as used in brass foundries. A hole a trifle larger than the shank is drilled into it, into which brass filings and borax, and the shank containing the diamond, are placed. It is then put into the fire in a forge and heated until the brazing is completed.

Splitting a Diamond

Figure 68 illustrates a method employed with success for breaking a large valuable diamond at a given point. The diamond was of an oval shape, about $\frac{5}{8}$ inch long, $\frac{5}{16}$ inch wide, and $\frac{1}{8}$ inch thick. The firm wishing to purchase this diamond informed the dealer that they would use it provided he would deliver it in two parts, cleaving it in the center so that each piece would be $\frac{5}{16}$ inch long, and $\frac{5}{16}$ inch wide. The dealer then informed them that the cleaving would increase the price of it considerably, because it would have to be cut with a thin disk the edge of which would be charged with diamond dust, a slow and costly operation. The dealer was then informed that one of the firm's men would undertake to part the diamond at a given point in a short time, and he at once consented to have him try it, saying that he was willing to learn, because he never saw a diamond of that shape parted successfully without cutting. A piece of

Fig. 68. — Breaking a Large Diamond.

bessemer rod $\frac{5}{8}$ inch diameter, and $1\frac{1}{2}$ inches long was secured, and an oblong hole was drilled and filed in it to receive the diamond, and after brazing it in, notches were filed a measured distance from one of the ends. After reaching the diamond from all sides and giving it the breaking strain, surprise was experienced in feeling it break more nearly like a piece of slag than like glass as was expected, but the break, nevertheless, was straight and clean, and at the given point.

Diamond Dust for Laps and Sapphires for Cutting Tools

The two above-named precious stones are extensively used in the making of small tools of precision, and as their use in connection with methods for accomplishing work is not widely known, a little information along this particular line will be of value and interest.

The use of the diamond in mechanical work is more extensive. The toolroom that does not possess a little black diamond for

dressing its emery wheels is a poor one indeed. But this cannot be said about the majority of toolrooms which do not keep the diamond in pulverized form, because often their class of work does not warrant it; but we have known of places where, if such an article had been at hand, it would have facilitated matters very much, and paid for itself twofold both in manipulation and results, on certain jobs.

This diamond dust comes in small vials and is classified by numbers, No. 1 being coarse, and as the numbers proceed the dust becomes finer. It is essential to assign certain numbers to cer-

FIG. 69. — Diamond-charged Lap.

tain classes of work, just as different grades of emery are assigned to different classes of work. Watch-tool work demands the use of this diamond dust, although there are many other classes of work on which it is extensively used.

For grinding out very small holes which may range from .025 to .250 in diameter, the diamond-charged lap in connection with a traverse grinder on a bench lathe cannot be equaled. A lap of this kind is entirely different from an emery lap, as will be seen from Fig. 69. It is made of mild steel and has a taper shank

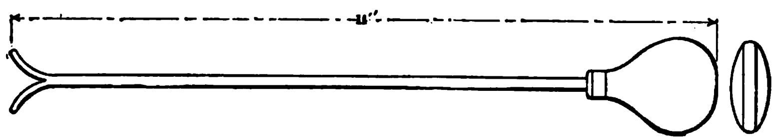


FIG. 70. — A "Harker."

which fits into the spindle of the traverse grinder. Soft metal for such a lap is desirable for the reason that it can be charged far more easily than if it were hard. The part of the lap which is to be charged is marked *A*. This charging is readily done by taking two pieces of steel which have been hardened very hard, surface one side of each piece, then holding one piece in the vise with its surfaced side up and placing thereon a little diamond dust which has previously been mixed with a drop of good oil, roll the lap between these two hardened pieces of steel and the diamond will be forced into the lap. A lap of this description does

its own grinding the same as an internal emery wheel, just grinding that part of the hole which runs eccentric, not following the hole the same as an ordinary emery lap does.

One of the most important items to be observed when doing this grinding is not to force matters, especially if the lap is of a very small diameter, as it will tend to follow irregularities of the hole and the result will be unsatisfactory. The lap should just hit the high spots in the hole and gradually grind them off. By placing a screw-driver or some such tool against the grinder's foremost bearing, at the same time holding the handle against one's ear, the sound when the lap first comes in contact with the work can be readily detected.

A more suitable tool for this purpose is shown in Fig. 70, it being termed a "harker"; it is nothing more than a piece of No. 30 drill rod inserted into a little piece of wood which is finished off to a suitable shape to hold against one's ear, the other end of the rod being split and spread fork shape so that it can be rested against the spindle or frame of the grinder. When grinding, if a lap is kept well lubricated with kerosene oil it will cut much freer and faster.

Handling Diamond Charged Laps

When doing this class of work it often happens that one must handle it entirely different from a larger piece. For instance, a piece of work 2 inches in diameter has a hole .040 in diameter; both must be accurately concentric with each other. Of course, if this were a larger hole it would be proper to grind the hole first and then place the piece on a true arbor and grind the outside, but this method would not be feasible in this case, as the arbor required would be too small. To accomplish work of this nature, a screw chuck may be made to fit the head of the bench lathe, as shown in Fig. 71; on this chuck is screwed a piece of brass which is a little larger than the diameter of the work to be held. Placing the chuck with the brass in position, bore out to a snug fit for the work (it should be understood that the work has been previously ground outside), then take a small alcohol lamp and hold it underneath the brass, warming it; this will allow the piece to be placed in position with ease. Remove the lamp and place a damp piece of cloth on the brass; this shrinks the brass and holds the piece securely and accurately. To release the work,

heat the brass as before, and the piece may be readily slipped out and another piece put in, if there should be any more such pieces. Any one who has never tried this method may think it a slow way, but it would surprise him should he try it, as very little warmth is required to make brass expand enough for this purpose. If the

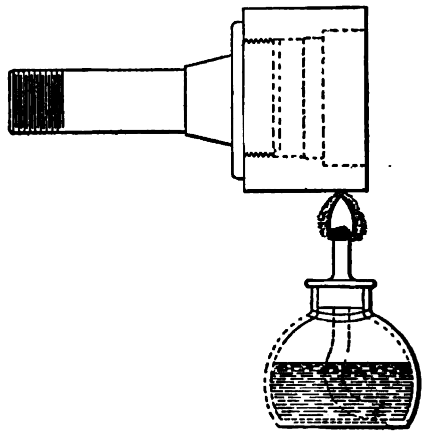


FIG. 71. — Screw Chuck for Accurate Grinding.

periphery of the piece that was being heated was out of round, then of course this method would not do. Some, accustomed to use either solder or beeswax, have found the above method superior both for accuracy and speed. Another style lap which

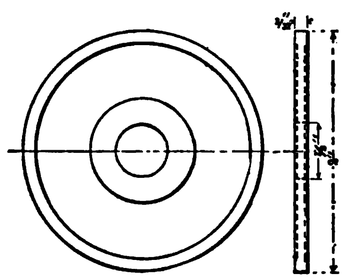


FIG. 72. — Another Style Lap.

it is quite extensively used is shown in Fig. 72; this is nothing more than a soft steel disk with its sides undercut. A lap of this kind is mostly used on a surface grinder for finishing out corners on small intricate tool work where an emery wheel would be useless.

Charging a Diamond Lap

For charging this lap the roller shown in Fig. 73 is utilized. This roller is made as hard as possible, and is held in a fork-shaped tool-post of the bench lathe. The lap is placed on an arbor which is held between the centers of the lathe. A little diamond dust mixed with oil is then distributed around the lap and the roller brought to bear against it; by revolving the lap the diamond is forced to imbed itself in the lap, repeating this until the lap is satisfactorily charged. The shaper also plays a prominent part in lapping out flat surfaces which are located in the side of a hole such as a die which has to be accurate as to size. The sketch, Fig. 74, show the construction of a shaper lapping device. The stud *a* takes the place of the tool-post; it is held in position by the threaded nut *n*. The forward part of *a* is milled out to form

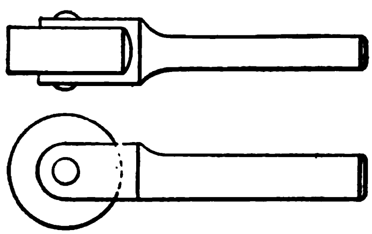


Fig. 73. — Roller for Charging Laps.

a tongue, on which fits the gray-iron lap *l*. A ¼-inch dowel which is a running fit in *a* lets *l* adjust itself in position. The length of lap is governed by its width and thickness, care being taken not to get the lap too long, as then it will spring and cause a convex surface. The screw *s* has a piece of drill rod through its head which allows it to be adjusted; while the machine is in motion it bears against a small disk, which in turn bears against a spring which puts pressure on the lap. Both sides of this lap may be charged, and for accomplishing this the roller shown in Fig. 73 is utilized, a handle being placed on the shank of the roller and the diamond distributed upon the lap; it is then rolled in with as much pressure as one can exert.

When the dimensions of the lap are large enough to allow a 10- or 12-inch stroke on the shaper to be had, then emery or carborundum is a very good substitute for diamond and is less expensive. Of course it will be noticed that it is essential to have

the working face of the lap travel in a true plane with the ram of the shaper in order to insure accuracy.

The Sapphire as an Abrasive, Reamer, Forming Tool, Etc.

Leaving the diamond we now turn to the sapphire, which is another precious stone which is handled quite extensively on very small tool work; this stone has been made into reamers, forming tools, and applied to many different tools. Of course, as regards reamers, it may seem absurd, but when we consider that they were only .040 in diameter and $\frac{3}{16}$ inch long it may look more reasonable. These reamers were made square which gave the

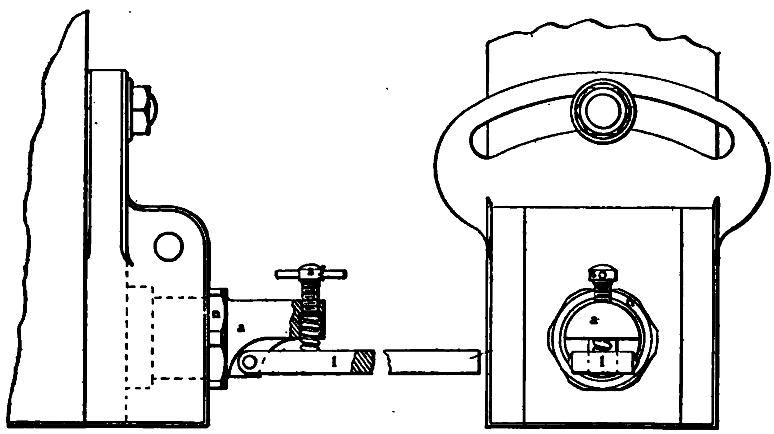


Fig. 74. — Lapping in the Shaper.

flutes, and also round with cutting teeth the same as a rosebit; they were used to finish out a hole which had to be accurate to size and in very tough phosphor bronze. The amount they had to ream out of each hole varied from .001 to .0015 inch. Steel reamers were used before these, but would lap under size in a few minutes. The sapphires stood up very nicely. They were ground up with the aid of a diamond-charged circular lap, this lap being the same as the one shown in Fig. 72, only smaller, it having a $\frac{1}{32}$-inch face and being $1\frac{1}{4}$ inch diameter. The reamer was held in a steel socket by means of jewelers' cement, which in turn was held, as shown in Fig. 75, in the taper shank by dowel *a*, it being allowed to float in position.

The sapphire forming tools which were of very small dimensions were held as shown in Fig. 76, these formers only acting as a sizer for a shoulder which had to be very accurate. The stock turned was soft steel and a steel tool preceded the sapphires. They were ground to shape in a surface grinder with the aid of a circular diamond-charged lap. Care must be taken when doing this kind of grinding to take a very small cut.

Sapphires have answered very well, on account of their hardness and smoothness, when set in the jaws of a special steady-rest which was used on a manufacturing job. One sapphire was set in the business end of each jaw, of which there were three; these were then lapped with the aid of a diamond lap to the true circle of the work which they were about to hold. For this special job they stood up remarkably well, being superior to anything that had been tried before.

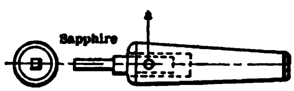


FIG. 75. — Taper Chuck for Sapphire Lap.

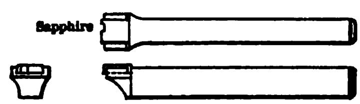


FIG. 76. — Holding Sapphire Forming Tools.

ROTARY AND SURFACE LAPS: THEIR MANIPULATION

It seems strange that a great many mechanics have an idea that if a rotary or surface lap has a perfectly true flat surface most any one can produce absolutely true results. Such, however, is not the case. There are several facts to be kept in mind. It requires considerable skill, especially when lapping thin pieces, small straight-edges or long narrow strips; and it is possible and requires no skill at all to lap a piece convex or concave on a dead level lap by using a little more pressure in one place than another; and if the surface of the lap is not kept sharp it will soon heat and peen the work out of true. Furthermore, the outer surface of the rotary lap travels faster than the center and of course laps faster than the center, so it is obvious that the work should not be held in one position. The heating and peening of hardened pieces is not so liable to occur on surface laps as on rotary laps. It will be found also that the less the lap is used near the center the easier it will be to keep its surface straight. This is probably

due to the speed being less near the center, which tends to roll and loosen the abrasive and therefore wears the surface more than where it keeps cutting.

With a great deal of practice, skill and good judgment both the rotary and surface laps can be kept in first-class condition; we have seen a lot of fine work done on laps and they did not have to be trued except at long intervals.

One rotary lap was made of an ordinary gray-iron disk mounted on a vertical shaft; it was faced and then provided with anchor holes or grooves. A coating of lead was then cast over the surface, and when cooled it was hammered to make it compact. Then it was faced up true, but not perfectly straight. It was left a little higher at the center, as it wears faster here on account of the speed being less; and by a little higher is meant two or three thousandths of an inch. It is provided with a pan all around, the edges of which project above the surface of the lap; a drip can for water is suspended above the center of the lap,

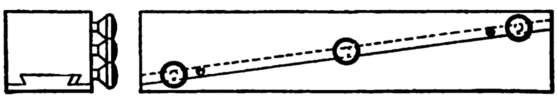


FIG. 77. — Lapping Block.

and when it is desired to lap a very thin piece without heating the water is allowed to drip freely.

Another handy device on this lap was a bar which was provided with ways, and a sliding head which traveled by hand from the outer edge to the center of the lap; it was fastened to projecting lugs at opposite sides of the lap frame and was also provided with means for adjusting the ways and the bar so as to stand perfectly square with the surface of the lap. The can could be easily removed when not in use. The sliding head had a square corner and an angle groove and was used for lapping the ends of round or square pieces. This lap was also tried charged with emery in cheese cloth and kerosene and gasolene, and it gave excellent results.

Rotary laps when not in motion may be charged by sprinkling abrasive over the surface and rubbing it in with a piece of round iron held in both hands. The surface lap mentioned above was used for finishing only, and was also a gray-iron platen covered with lead; it was charged the same as the rotary lap.

Adjustable Lapping Block for Snap Gages

A small and inexpensive tool is shown in Fig. 77. This no doubt is familiar to a good many, nevertheless it may be that its usefulness is not fully appreciated, so a few words in regard to it may not be out of place in this section. It was made for lapping snap gages, after these had been ground out to within .0005 inch of size, and Fig. 78 will give the reader a clear idea of the

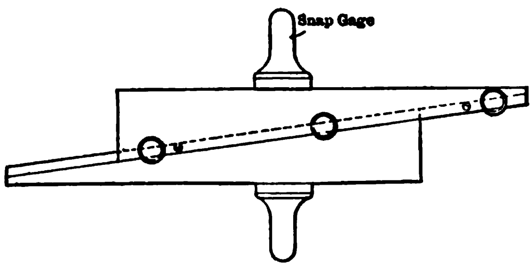


Fig. 78. — Lapping Block.

manner in which it was used. The body, which is made of cast iron, is composed of two pieces held together by a dovetail joint and gib. Two small screws serve to lock one sliding member of the body at any point along the other. To accomplish accurate lapping, the lap is first ground off so that both sides will be perfectly parallel, then each side is charged with flour of emery from a large bench lap. This adjustable lap is suitable for finishing snap gages ranging from ¼ to 1¼ inches in size.

Making and Lapping Flat-end Gages

The making of flat-end gages or end test bars is generally supposed to be a difficult job, and experience has taught that the

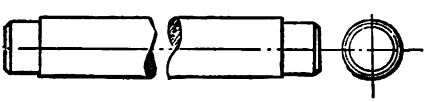


Fig. 79. — Flat-end Gage.

Fig. 80. — Flat-end Gage.

supposition is a correct one. Gages are of course made with varying degrees of accuracy, but we will take up the making of a test piece which is right and will stand the test in every way.

Most gages 3 inches or over in length are made like Figs. 79 and 80

because they are easier to make, the ends being turned a little smaller than the body, as shown, so that after hardening cat-heads may be fitted to the ends, and the body ground true and parallel, this making a cheap method of truing up and finishing. These round gages have a faculty of rolling away and getting lost, and for this reason we do not think they are as desirable as square ones, although the rig described will make them equally well.

To make a 1-inch standard test piece such as the Pratt & Whitney Company furnish, and which is shown in Fig. 80, a piece of tool steel of 110 points carbon is milled $\frac{11}{32}$ inch square and to a length of about .01 over 1 inch, after which the corners are milled with a 45 degree cutter, leaving the end surfaces to be

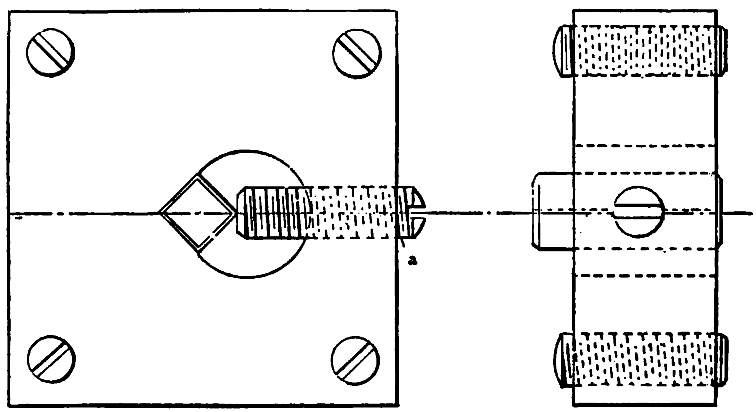


Fig. 81. — Cast-iron Piece.

finished about $\frac{1}{4}$ inch square. Next a $\frac{3}{32}$-inch hole is drilled in the middle and countersunk with a center reamer; and after the corners have been nicely rounded the gage is ready to harden.

To get the best results, it should be packed and the ends hardened in oil, as the oil will give a nice dead-black finish. Next two adjacent sides are ground on a surface grinder and lapped square.

Now we are getting where things *must* be right, so we will test with a knife edge square, drawing the fingers crosswise over the gage and then drawing the square endwise and noting the marks made by the blade in the moisture left on the surface by the fingers. This, in our opinion, is better than the light test.

We are now ready to finish the ends, and for this a piece of

cast iron 3 inches square and ¾ inch thick, as shown in Fig. 81, will do, care being taken to have the corner screws tapped in square and a snug fit, and the corner for the gage scraped to a good surface, for we must be able to remove the gage and return it absolutely to the same position. Next, this lapping jig is placed on a true mandrel, secured by a screw *a*, and the corner screws adjusted on the lathe center with a test indicator. We now place the jig on the surface grinder with the gage in position, as shown, and grind one end.

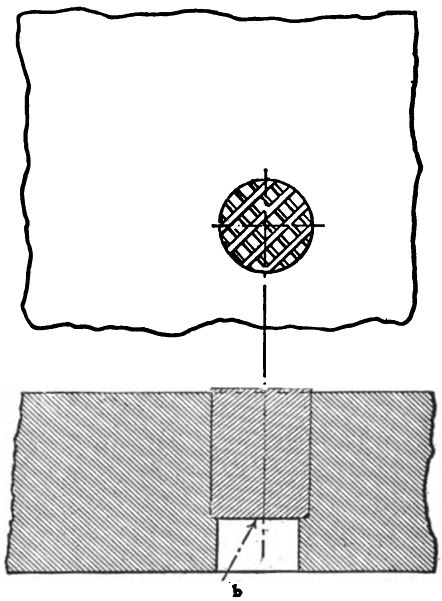


FIG. 82. — Plate Required for End Lapping.

The plate in Fig. 82 is now needed. It is of cast iron with a ½-inch brass plug *b* driven securely in, planed off $\frac{1}{16}$ inch above the surface and checked as shown. A drop of oil and a pinch of flour of emery (diamond dust is better) are placed on plug *b*, the jig is placed in position, and the gage dropped into place and secured by screw *a* with the ground end down, care being taken not to turn *a* so tight as to spring the jig.

It becomes interesting now. Tapping the gage lightly with a piece of brass rod to seat it on the lapping plug, it is lapped until the surface is cleaned up, when it is removed from the jig and

tested with the knife edge square, notice being taken of the way the jig is out; the corner screws are then adjusted to correct the error and the lapping process is repeated. This is kept up until the end is square with both finished sides, and it must be right for any error here will be doubled when the outer end is finished.

When the end is square and a suitable surface secured, the jig is placed on the surface grinder, the other end ground, leaving about .00025 inch to finish — or less if the wheel is fine and true — and the lapping process is repeated. This time as the jig is adjusted we have to deal with the length only, but great care must be taken now. New abrasive material must not be put in the lapping plug when near the finish, or scratches will be made that cannot be taken out without making the gage too short; and the work must not be handled, as it will expand with the heat of the hands, so a small stick is thrust into the hole at this point to hold it while measuring.

One of these little blocks of steel that is *right* may not look very much to the average eye, but it is a work of art nevertheless.

Lapping and Testing Small Holes

The following relates to bushings that are not to be ground out but worked as they come from the hardener. There is one

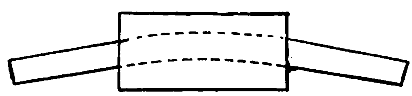


Fig. 83. — Seemingly Straight Hole.

point in this work that is not given enough attention in small holes, say from .10 inch down as small as you can go, for the small ones are the easiest to be deceived with. Fig. 83 shows (exaggerated) what a seemingly straight hole would test up to in the gage, Fig. 84, to be described later. In lapping this hole it is very easy to say it is small in the center, and ease it there so that the fit seems to be even. Think of a drill running in such a hole — and there are lots of them, and gages, too, with a hole of this kind.

Figure 85 is a lap which gives satisfaction. A taper pin that fits into a taper hole gives a good, solid adjustment for wear. There are two slits starting from a hole drilled through the lap

about $\frac{1}{8}$ inch from the end, and extending to another hole which is at a sufficient distance to give an easy spring to the lap. Put two slits in laps, .1875 down to .080, using a fine fret-saw blade. Laps below .080 ream out, so there is only a thin shell left that will expand without slitting when the arbor is tapped in. In holes too small for taper pins drawn brass wire may be used. To enlarge it use a hard steel V-block, the "V" being the light size to allow a flat piece to be placed on the top of the wire and struck with a hammer; sometimes the wire is turned if it can be done conveniently. Laps above .1875 inch can be used on the taper arbor held in the chuck. The metal for outside lapping should

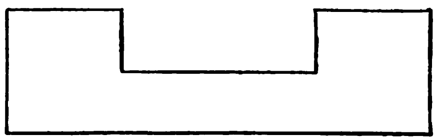


FIG. 84. — Gage for Fig. 83.

be gray iron for roughing and pure copper for finishing. Abrasives from good manufacturers run very close to what they are sold for. Brass or gray-iron is full of dross which will leave marks on highly finished steel. In lapping small holes finish with drill rod tinned over and trued off.

The bell-mouthing of holes by lapping is caused by two things. A lap flooded keeps the ends of the hole always charged heavily;

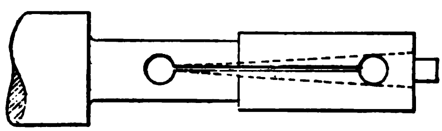


FIG. 85. — Lap for Small Holes.

a lap run dry, as the tightly fitting portion comes out of the hole, expands — and it does so when flooded — and putting a greater pressure on a narrowing surface, produces a bell mouth. This works both ways; for a lap is large and must be compressed as it enters the hole, which helps increase the bell mouth. The nearer solid a lap is, the less trouble there is in using it, and Fig. 85 comes as near as you can make an adjustable lap for small sizes. Leave $\frac{1}{16}$ inch on each side of the bushing for bell mouthing, and when you grind it to length you will find that the hole is a little small at each end and will have to be touched out a little in most cases.

The length of the lapping part of the lap for a hole that is finished to length should be one-half of the length of the hole. In lapping a hole that is finished to length use a lap that is about one and a half times the length of the bushing and charged by rolling between two hard, flat surfaces, then wiped almost dry by the hand. This lap shows us that the hole is not made hollowing with the narrow lap.

A simple test to find the error in a piece like Fig. 83 is to rough lap the hole and then turn a pin in the lathe long enough to stick through to test with an indicator. With very small holes take a piece of gray iron, Fig. 84, and plane a channel wide and deep enough to let the pin rest on the flat surface. If the pin lies flat on this surface before it is put in the bushing, it should while in the bushing rest with the ends sticking out about ½ inch.

Use half kerosene and lard oil for a lubricant, and diamond dust for small holes, or be satisfied with what carborundum will do, though this will make you renew laps, often.

Casting Lead Laps

The sketch, Fig. 86, shows a mold for casting lead laps. It is simply a wooden box to be filled with plaster of paris, and *C* is an

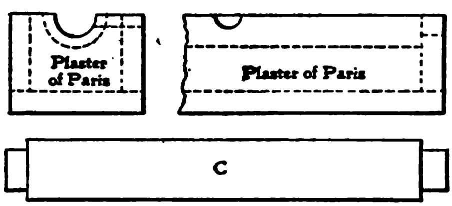


Fig. 86. — Mold for Casting Lead Laps.

arbor for pressing into the plaster to form the mold for the size of lap required. The ends of the box are cut to a ¾-inch semicircle and a groove is cut in the middle of one side for pouring. The box is filled with plaster of paris, and while this is still soft the arbor is pressed into it, and with the arbor in the mold the plaster is allowed to set. Then the arbor is taken out and the other half of the mold is made in the same way. The iron core upon which this lap is to be cast has numerous holes drilled part way into it to hold the lead firmly. The core is laid in its place and the halves of the mold are clamped together. The hole for pouring

the lead should be on the center line, allowing the mold to be easily taken apart after the lap is cast. This mold can be used for casting many laps, and it requires but a small allowance for turning.

A Lapping Fixture for End Lapping

Figure 87 is a cast-iron lapping fixture with hardened steel shoes inserted in the bottom and held in place with hardened steel screws. These pieces must not fit tight at the sides. Piece *a* is pivoted on the lower screw, which must be a very good body fit and true; the top screw works in an elongated hole and has a head large enough for a good bearing.

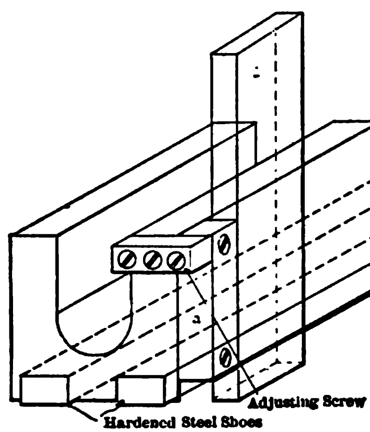


Fig. 87. — Cast-iron Lapping Fixture.

Piece *B* is to be lapped square on the ends, and is held in the position shown by the fingers of the right hand, so there will be a pressure diagonally toward the inside corner; use rubber tips on the fingers and they will give you all the grip necessary for the pressure down on the lap. This fixture will do a good job after a little practice with it, holding the work, and it makes a good angle iron for holding work to grind the ends square. The other side is left plain for thin pieces, which require lapping flat and square on the edges.

When lapping thin pieces look out for "plowing"; if this shows up the surface will be crowning. Lap lengthwise and a little diagonally, holding the work against the fixture with the

fingers; if the work is very thin and long, use a flat strip between it and the finger. This fixture, if rightly made, can be trued off on the hardened shoes — which are above the surface, about $\frac{1}{16}$ inch — by placing it on the opposite edges and grinding the shoes off true when they have worn out of square with the sides by use.

If in doubt about the accuracy of the grinder chuck, place a couple of pieces on the chuck and spot them off true; place the fingers on them and up against the back rest, then grind the steel shoes off lengthwise.

A Shaker for Lapping Emery

It will be of interest to describe and illustrate an emery shaker that was designed and found a useful and very convenient addi-

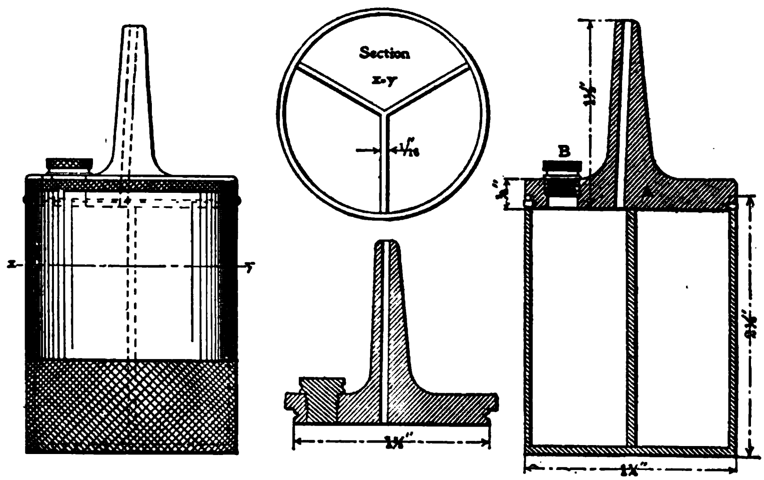


Fig. 88. — An Emery Shaker.

tion to the tool-room outfit, as it dispenses with the numerous dishes, cans and packages that are generally used to hold the various grades of emery required in lapping and polishing. The model, Fig. 88, was made from solid brass with three compartments, which was found most suitable for general work, although the device can be divided into six compartments if preferred. The partitions were cut from sheet brass and soldered in place. The body can be made from tubing, but a casting is better. The cap must be a good fit to prevent emery from passing the partitions.

The stem is drilled out of line at the base to clear the partitions, so that by turning the cap *A* each compartment in turn will be free to discharge the emery while the other compartments are closed. Plug *B* can be dispensed with, although it is convenient when refilling as it saves the trouble of removing the cap.

Outside of the compartments should be stamped the letters *F*, for fine; *M*, for medium; *C*, for coarse; and the cap should be graduated to indicate when it is in the right position to discharge, or when closed by stopping over partitions.

A Pair of Lapping Emery Stick Holders

Where there is considerable work to do on small dies, plenty of lapping is necessary to bring them back to shape after harden-

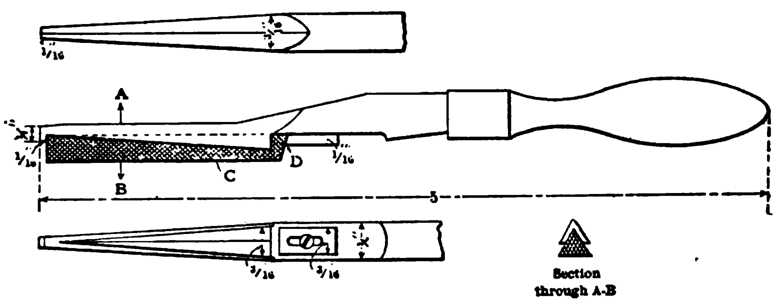


Fig. 89. — Emery Sticks for Lapping.

ing, and the ordinary emery sticks, when a little pressure is put upon them, break very easily. Where so many break, it is found a big waste to have a lot of short pieces that are almost useless, and so the holders can be made as shown in Figs. 89 and 90. With these most of the pieces can be used and besides more pressure can be put on them, with the result that the work is done quicker and better and there are not so many sore fingers.

The holder, Fig. 89, is for a triangular piece, and is made of tool steel. The emery stick is beveled off on the back so that the plate *D* holds it from falling out. The lip on the front end holds it from going forward, and when the piece is put into the holder one of the angles fits in the groove cut in the holder, so that prevents any side motion. It will suit any size of triangular piece, for all it has to do is just fit in the groove. It will be

noticed that the groove increases in depth from the front end back to plate *D*, but is cut parallel to the body of the holder. The reason for cutting it away at the front end is so that one can see what he was doing, and this is very advantageous in many cases.

Figure 90 is for a square piece, and has a lip on the end the same as Fig. 89, but the emery stick is held in place by the side lips and screw *c*, which, being tightened up, draws the lips *E* together. It will be noticed that the holder is slotted so that the screw *c* can pinch the lips in on the emery stick. These lips are only ½ inch long, and the size of stick they will grip is ¼ inch. If a wider piece is required, all that is necessary is to grind it away till it fits between the lips. It is almost surprising how solidly the pieces are held in position, and the work of lapping, which every mechanic knows is so hard on the fingers, is made

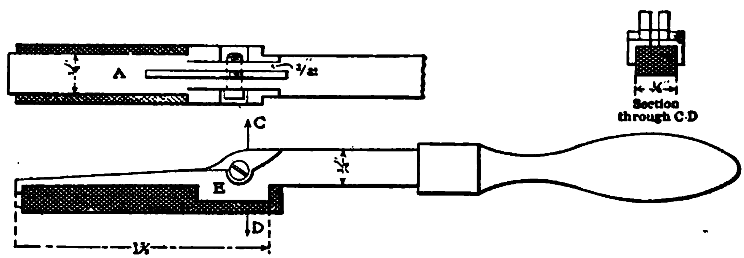


FIG. 90. — Emery Sticks for Lapping.

comparatively easy. They are not costly tools to make and the time taken to make them is soon gained on the work. Other pieces of emery sticks can be made to fit these holders for certain special jobs.

LEAD LAPPING A STEEL-LINED CYLINDER

We hear much about grinding machines nowadays, inside and outside grinders, surface grinders and grinders of all sorts; and as the producers and users of machinery become more skilful, the demand for and ability to construct more accurate and efficient mechanical appliances lead to an increasing use of abrasive processes. The grinding machine itself, in its many forms, comprises a distinct class of highly developed machinery, the history of which would, no doubt, be very instructive and interesting.

The accompanying sketch, Fig. 91, is of a "grinding machine"

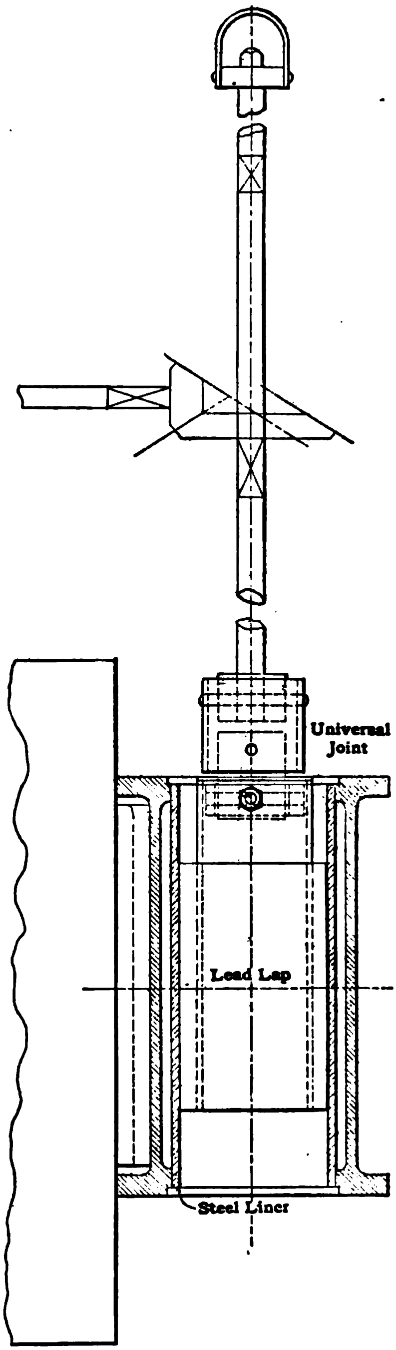


FIG. 91. — Grinding Machine for Cylinder.

used some years ago in producing smooth and accurate cylinders for compressing gas. The principle used, the lead lap, probably familiar to most readers, is doubtless one of, if not the chief, progenitors of the grinding machine.

An old Dallett portable drill was stripped of everything except the base, frame and gearing. A piece of shafting of the same diameter as the drill spindle, and of proper length, was key-seated its entire length; one end being attached by a universal joint to a piece of pipe, around which was cast the lead for the lap. This joint was made in the cheapest manner possible, of pieces of pipe, a piece of round iron and rough iron pins. To the other end of the shaft a loop was attached by a bolt upon which it turned easily. The lap was turned so it would slip easily through the cylinder as it left the boring mill, and was provided with four large grooves extending about two thirds the way down from the top, to conduct emery and oil.

The cylinder was bolted to one side of a large T-slotted cast-iron block, with the Dallett drill on the top, and the shaft put in, in place of the spindle, and centered roughly with the cylinder by the eye. A light block and tackle were attached to the loop at the top of the shaft and to the ceiling of the shop, the usual portable drill drive connected up, and a can of oil and box of loose emery being provided, everything was ready for beginning operations with the internal "grinding machine."

The speed and accuracy with which the work was accomplished by this contrivance would probably be surprising to some. From three to four hours sufficed to make a 7 x 18 cylinder, lined with forged steel, perfectly smooth and of uniform diameter within .00025 inch. The lap would grind out about four cylinders without renewing, when the lead would be recast on the pipe and turned to size again. Of course there was a few thousandths variation in the sizes of the cylinders, which is obviated in improved machines for this kind of work.

Diamond Power and its Use in the Machine Shop

The diamond used for this purpose, costing $85 per carat, is an inferior grade of diamond, not so hard as the black diamond used for drills and truing emery wheels, and not of a clear and perfect structure to permit it to enter the gem class. Many of them

are a mixed black and white, others yellow and some pink; many are clear but flaky. Then there is the small debris from diamond cutting, which is reduced to powder and sells somewhat cheaper; but we find it more economical to use the above and powder it ourselves, as the debris from diamond cutting is of a flaky nature and does not charge into the lap so well.

Assuming we have 25 carats to reduce to powder, we proceed as follows:

Into a mortar, as shown in Fig. 92, we place about 5 carats,

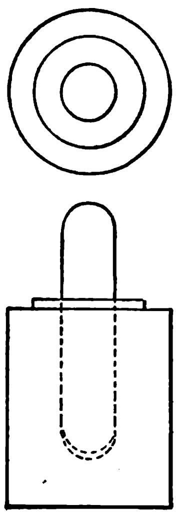


FIG. 92.—Mortar for Pulverizing Diamonds.

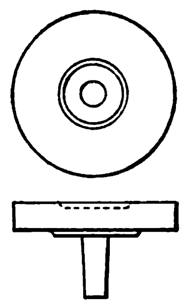


FIG. 93.—Copper Lap for Small Drills.

using an 8-ounce hammer to crush it. It takes from four to three minutes' steady pounding to reduce it to a good average. Scrape the powder free from the bottom and the sides and empty in one-half pint of oil. The oil is the best olive oil obtainable, and is held in a cup-shaped receptacle that will hold a pint and one half. The 25 carats being reduced to powder, and in the oil, we stir it until thoroughly mixed, and allow to stand five minutes; then pour out to another dish. The diamond that remains in the dish is coarse and should be washed in benzine and allowed to dry, and should be repounded, unless extremely coarse diamond is desired. In that case we label it No. 0. Now we stir that which has been poured from No. 0, and allow to stand ten minutes. Then pour

off into another dish. The residue will be No. 1. Repeat the operation, following the table below.

The settling can be put into small dishes for convenient use, enough oil staying with the diamond to keep it the consistency of paste. The dishes can be obtained from a jeweler's supply house.

TABLE FOR SETTLING DIAMOND

To obtain No. 0 — 5 minutes.
To obtain No. 1 — 10 minutes.
To obtain No. 2 — 30 minutes.
To obtain No. 3 — 1 hour.
To obtain No. 4 — 2 hours.
To obtain No. 5 — 10 hours.
To obtain No. 6 — until oil is clear.

Diamond is seldom hammered; it is generally rolled into the metal. For instance, we desire several pieces of wire of various

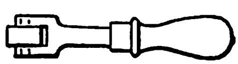


FIG. 94.— Roll for Charging Lap with Diamond.

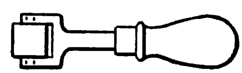


FIG. 95.— Roll for Charging Lap with Diamond.

diameters charged with diamond for use on die work. We place the wire and a small portion of the diamond between two hardened surfaces, and under pressure roll back and forth until thoroughly charged. No. 2 diamond in this case is generally used. Or you can form your metal any desired shape and apply diamond and use a roll, as Fig. 94, to force the diamond into the metal. You then have a file which will work hard steel, but remember the moment you crowd your diamond file, or lap, you strip it of the diamond, and it is consequently of no use. It is to be used with comparatively light pressure.

Copper is the best metal. It takes the diamond readily, and retains it longer than other metals; brass next, then bessemer steel. The latter is used when you wish to preserve a form that is often used.

For sharpening small, flat drills, say 0.008 to 0.100 (metric), a copper lap mounted on a taper shank, as Fig. 93, and charged

on the face with No. 2 diamond, using pressure on the roll, makes a most satisfactory method of sharpening drills.

The diamond lasts for a long time if properly used, and there is no danger of drawing the temper on the drill. It is much quicker than any other method of sharpening.

To change the lap we should use the roll Fig. 95, supported on a T rest pressing firmly against lap, being careful to have the roll on the center; otherwise, instead of charging the lap we should be grinding the roll. The diamond may be spread either on the lap or on the roll, and the first charging usually takes twice the amount of diamond that subsequent charging takes. To avoid loss of diamond, wash the lap in a dish of benzine kept exclusively for that purpose. This can be reclaimed by burning the metal with acids, and the diamond can be resettled.

For the grinding of taper holes in hard spindles or for position work in hard plates, where holes are too small to allow the use of emery wheels, No. 1 diamond does the work beautifully. Or if you wish to grind sapphire centers or plugs as stops, etc., a bessemer lap made in the form of a wheel and charged with diamond on the dimeter does the work nicely.

There are many ways which will suggest themselves where diamond powder can be used to great advantage. Nos. 5 and 6 diamond are used on boxboard laps, mounted on paper plugs or chucks, and the diamond smeared on with the finger. It is run at high speed and used for fine and slow cutting, which also gives a high polish.

SECTION III

CONSTRUCTION, USE AND OPERATION OF GRINDING FIXTURES AND JIGS FOR FINISHING REPETITION ARTICLES OF METAL, SMALL HARDENED AND TEMPERED STEEL PARTS AND SPECIAL WORK.

Value of Grinding Fixtures

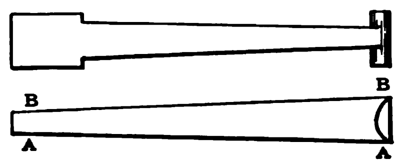
Methods of accomplishing lathe, milling machine, planer and drill press operations of almost every conceivable description have been published from time to time during the past few years, but it is very seldom that one encounters an article on grinding methods and fixtures for interchangeable work. Neither has there been much matter published pertaining to universal, surface, tool or special grinding. As these tools and fixtures now form an important part of the equipment of the modern machine-tool and industrial machinery manufacturing shops, there have been developed innumerable useful, novel and labor-saving methods as well as a large variety of ingenious devices, arrangements and tools for doing accurate work that will be of interest. Again there are many who are experiencing difficulties in finishing work by grinding, or have fault to find with methods that have been in vogue so long that they would be quickly relegated to the mound of obsolete things mechanical if better ways and processes were made known to those using them.

It is for the benefit of those mentioned in the above paragraph that we have gotten together in this chapter a large number and variety of illustrations and descriptions of devices and fixtures used for assuring the accurate production of work by grinding. These fixtures have been chosen from a large number because they represent in our opinion advanced practice, design and construction, and also possess many features which will permit of their principles being embodied in other fixtures for ma-

chining work of design similar to that for which they were made. The labor-saving features, the superior quality of the work machined through their use, and the total elimination of uncertainty as to interchangeability in their products, will make them of value to all interested in the production of accurate machine parts and articles of metal. Especially is this so where perfect interchangeability in small hardened and tempered parts of steel is desirable and imperative; while in special work the fixtures show how many operations may be accomplished easily and cheaply, operations, which, performed by other means, consume much time and labor and are costly.

A Grinding Fixture for Slender Taper Parts

Figures 96 and 97 show two views of a piece of work made in large quantities, and which was required to be accurately fin-



Figs. 96 and 97.—The Work to be Ground.

ished all over by milling, then hardened and afterwards ground on the sides *A* and *B*. It will be noticed that the piece is tapered in both width and thickness, hence is a difficult part to handle as far as positive locating and fastening for grinding is concerned.

The fixture designed for the work is shown in Figs. 98 and 99. *C* is a gray-iron casting, with two tapped holes for securing it to the cross-slide of the grinder, and *D* is the seat or locating plate for the work. This piece is of tool steel, ground tapering on the face, as shown in the top view, and fastened to *C* by screws let in from the back. *E* is an end or locating stop, and at *F* are five hardened and ground steel blocks which are fastened to *C* by screws and dowels. These five blocks support the work and locate it positively for hight on piece *G*, which is fastened in a shallow channel in *C* by three screws.

The clamping of the work on the blocks *F* is accomplished by means of five clamps *H*, which are of tool steel and hardened. To

insure their locating the work squarely and positively the rear ends are provided with inclined faces contacting with piece *I*, as shown in the end view. Thumb-nuts *J*, studs *K* (secured by pins) and springs *L* complete the clamping apparatus.

To eliminate the necessity for the operator holding the work by hand against the seat *D* when tightening the clamps, three spring fingers *M* are provided which consist of $\frac{3}{16}$-inch drill rod bent over for a distance from the other end; each finger is provided with a spiral spring *N*, an adjusting nut *O* and a nurled head *P*. By pushing in on *P* and giving a half turn to the head the bent end of the finger is brought against the face *A* of the

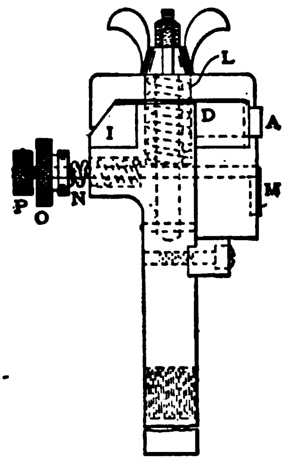


FIG. 98. — End View of Fixture.

work; then the clamps are tightened down and the spring fingers are released from the work by giving them a half turn backward and out of the way, leaving a free surface for the emery wheel, which is an 8-inch cup wheel.

With this fixture the grinding operation is an extremely simple and inexpensive one to perform, and the means adopted for locating the work insure interchangeable production.

Two Grinding Fixtures for Small Dovetail Parts

The two grinding fixtures illustrated by Figs. 100 and 101 were used in the production of small interchangeable work requiring

great accuracy. The work is shown in Fig. 102, where *A* represents a nearly square piece of tool steel $\frac{3}{32}$ inch thick, which has four holes punched through, and two sides milled dovetail; and *B*

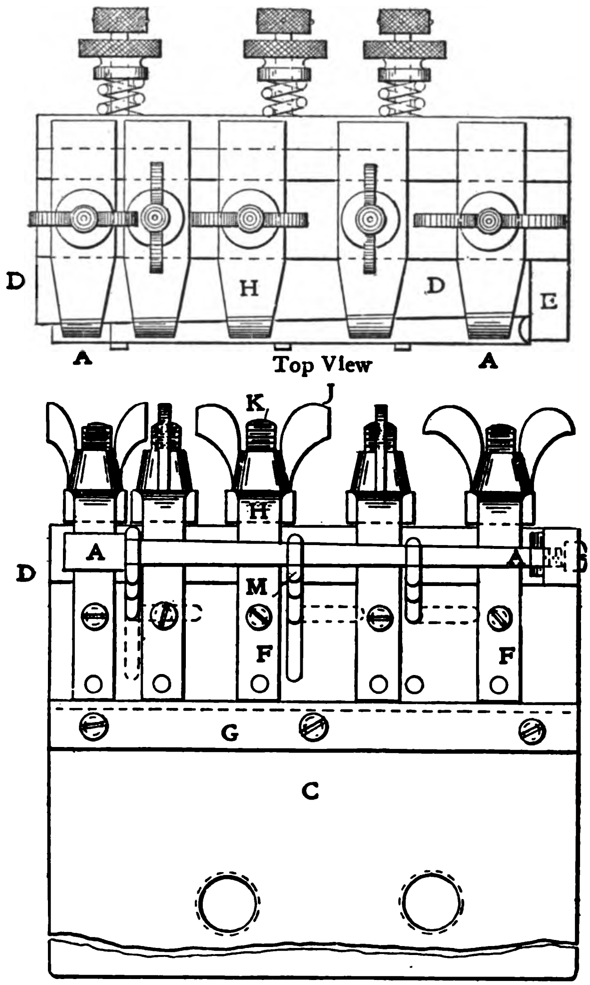


FIG. 99. — Grinding Fixture for Work, Figs. 96 and 97.

a tool steel plate to which *A* is riveted after the milling of one side, the punching and countersinking of the holes and the milling of the dovetail surfaces. So much for the work.

Piece *A* comes to the first grinding operation as shown in Fig. 102. This operation consists of grinding one side off in the

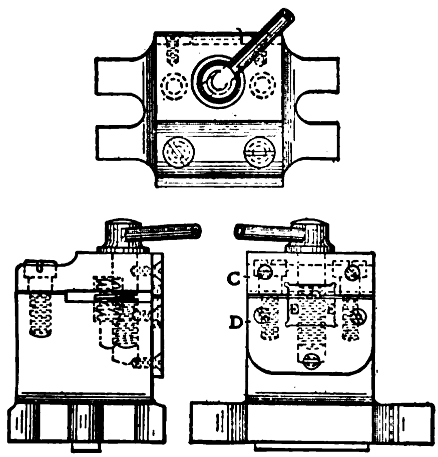


FIG. 100. — Grinding Fixture for Small Work.

fixture illustrated in Fig. 100. As the tool-steel blanks are accurately punched out in the power press from straightened sheets, they are of the same size and easy to locate and fasten.

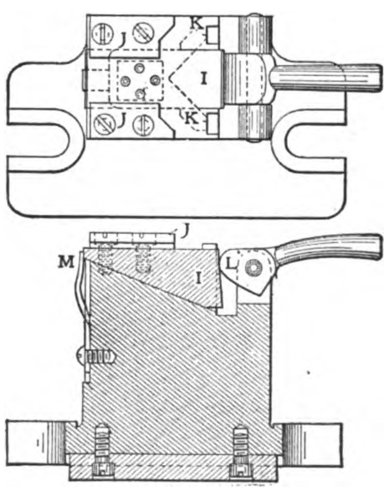


FIG. 101. — Grinding Fixture for Fig. 98.

The three views in Fig. 100 show the fixture construction quite clearly. The gray-iron body has a locating tongue at the bottom,

and at the top a movable clamping jaw located by fillister-head screws and actuated by two springs and a clamp handle. *C* and *D* are jaws of tool steel, which are fastened to the fixture and clamp by flat head screws as shown. *E* is the seat where the work is clamped for grinding.

The fixture is clamped to the platen of a small hand grinder, and the work located and released by merely tightening or loosening the clamping stud. A cup wheel does the surfacing.

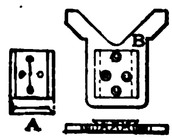


FIG. 102. — The Work to be Ground.

The second grinding operation consists of grinding the other side of *B*, Fig. 102, that is, flushing the rivet heads with the stock and cleaning the surface to size. For this work the fixture shown in Fig. 101 is employed.

The dotted outlines in the plan view indicate the position of the work when located and clamped within the fixture. *I* is the clamping slide, *J* the locating plates up against which the work is clamped, *K* the back stops. *L* is the actuating cam for the taper shoe or clamp *I*, and *M* is a stiff, flat spring, which causes the clamp slide to descend abruptly when the lever is raised.

Grinding Fixture for Thin Taper Parts

Figure 103 is an interchangeable tool-steel part which was required to be ground taper on one side, as indicated. This is the

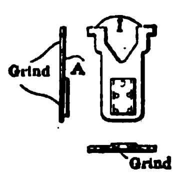


FIG. 103. — Interchangeable Ground Part.

part described in the preceding section, but we now grind the back side of the large piece. This part consists of two accurately machined pieces, held together by five rivets. In producing the

article the larger pieces were punched from sheet-steel strips, the holes for the rivets were pierced and countersunk, then the sides were milled, after which they were hardened. After this the surface *A* was ground and then the dovetail piece riveted to it as shown. After assembling, the smaller or dovetail piece was shaved on the edges to insure interchangeablity by means of special cutters. The variation in the ground part was not to exceed .0005 inch.

Figure 104 shows the grinding fixture complete and also a few of the details. The body is of gray cast iron, with holes and a slot for the bolts which fasten it to the cross-slide of the grinder

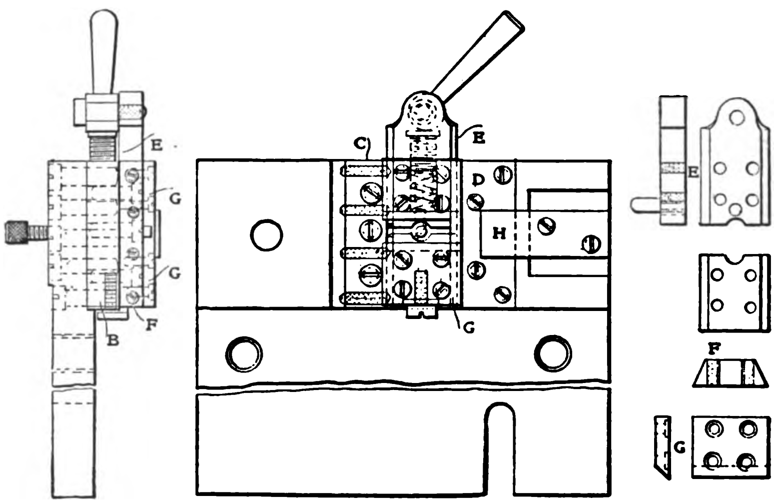


FIG. 104. — Grinding Fixture for Fig. 103.

and in alinement with the cup emery wheel. *B* is a machine-steel plate fastened to the base by fillister-head brass screws, let in from the back; *C* and *D* are two guides between which the dovetail slides *E* and *F* fit; *G G* are the work-holders and locators. A fillister-head screw adjusts *F*, and an eccentric lever raises *E*. At the rear of the latter is a headless screw, which regulates the tension of a spring acting upon slide *E*; this screw is engaged by the eccentric portion of the lever. The nurled head screw tapped in from the rear of the base forms a seat against which the dovetail piece of the work rests. The plate *H* is the stop against which the wings *I* of the work locate when the fixture is in use.

The fixture is clamped to an inclined surface on the grinder cross-slide, and when the operating handle is pulled to a vertical position, opening the jaws, the work is slipped in with the dovetail piece between the jaws and the wings against the stop *H*, after which the handle is pushed downward, when the spring engaging pin in slide *E* causes the work to be clamped securely. The nurled-head screw is then brought against the work, the feed thrown in and the piece ground, under a good flow of water. Altogether, thirty brass screws were required to hold the parts together, there being, of course, no possibility of these screws rusting in under the action of the water.

A Fixture for Accurate Edge-Grinding

Figure 105 illustrates a tool-steel part which was accurately milled to shape, and then ground on the edges. The grinding

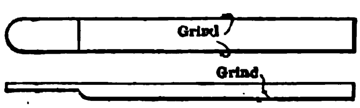


Fig. 105. — The Work.

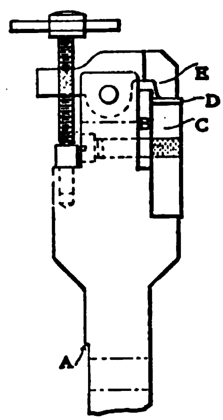


Fig. 106. — Grinding Fixture for Fig. 105.

fixture is shown in Figs. 106 and 107. The body is machined all over, with a ledge at *A* for locating the fixture on the cross-slide of the grinder, and in alinement with the cup-shaped emery wheel. The tapped holes are for fastening bolts. *B* and *C* are two hardened and ground tool-steel plates which comprise the seat for the work *D*. The latter is clamped into the seat by the tool-steel clamp *E*, which is hinged on a pin and operated by a thumb-screw, the point of which rests on a steel plug, as shown in the end view, Fig. 106.

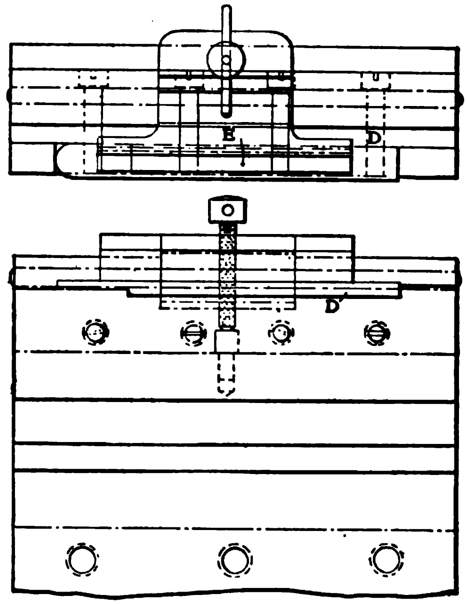


FIG. 107. — Grinding Fixture for Fig. 105.

GRINDING FIXTURE FOR THIN TAPER WEDGES

Figures 108 to 111 show a grinding fixture used for holding a piece of work, Fig. 112, while the tapered face is being ground.

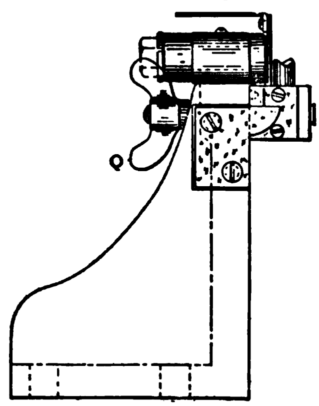


FIG. 108. — Grinding Fixture.

The piece is tool steel, milled to snap-gage measurements all over; it is dovetailed at *C*, milled taper from *D* to *E*, and has a

section punched out at *F*. It is then hardened, drawn or tempered at 550 degrees Fahrenheit and then ground on both sides.

Now, in order to grind so wide a surface as that indicated on a piece of duplicate work so delicate as the one in question, care-

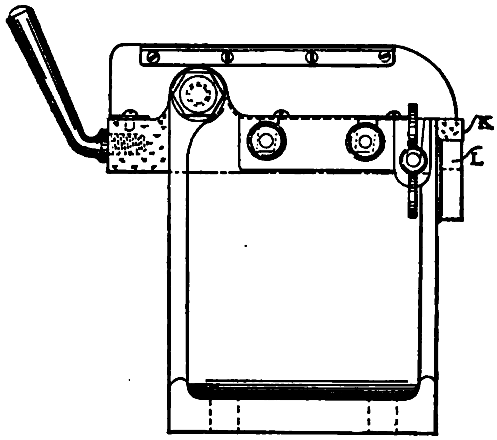


FIG. 109. — Grinding Fixture for Fig. 112.

ful provision has to be made to insure its non-springing when the cup-emery wheel engages it. The fixture illustrated proved all that could be desired along this line.

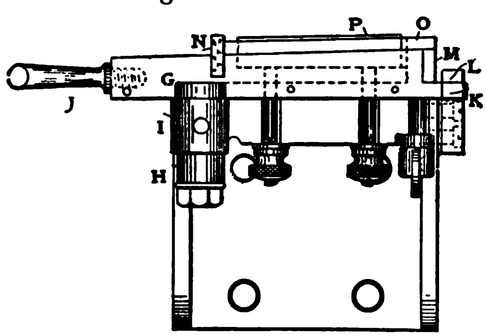


FIG. 110. — Grinding Fixture.

The angle plate forming the base is accurately surfaced on the bottom and at the front, and has four holes for bolts which fasten it to the cross-slide of the grinder. The locating and clamping portions of the fixture are combined so as to be movable upon the base. The main part of the arrangement (shown in

detail in Fig. 111,) is a machine-steel forging with a lug at *G*, into which a cap-screw enters. This screw passes through and fits a steel bushing *H*, which takes a bearing in boss *I*. A small headless screw holds the bushing in place. Thus the work holder — when the fixture is alined in position with the wheel — can be swung upward and outward by merely loosening the fastening screw and pressing on handle *J*.

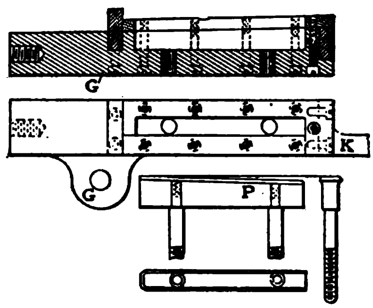


Fig. 111. — Fixture for Work, Fig. 112.

For securing the work in position for grinding, accurately ground and lapped steel plates and a dovetailed clamp are depended upon. As will be seen; *K* is a projecting end of holder *G*, which locates the swinging head in the correct position by resting on steel plate *L*, which is secured to the base by fillister-head screws. *M*, *N* and *O* are hardened, ground and lapped steel plates, all of which are secured in seats machined in forging *G*.

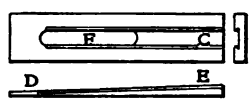


Fig. 112 — The Work.

P is the dovetail clamp, whose inclined surface engages the dovetail slot in Fig. 112. The clamp has two studs with nurled nuts to tighten or release it.

The fixture is clamped to the grinder cross-slide in alinement with the 10-inch cup wheel. The nurled nuts on the clamp studs are loosened, and thumb-screw *G* is unscrewed to release the holder *G*. The handle *J* is forced downward, swinging the holder

up. Then the work is slipped onto the dovetail piece *P* and against stop *N*, after which the holder is dropped to the working position shown. The thumb-screw is then tightened, the nurled nuts screwed up, the feed thrown in, and the work ground, a good flow of water running on it the while.

With this fixture, work which does not vary .0005 inch from the required dimensions is produced at an extremely low cost, by comparatively unskilled help working by the piece.

Grinding Fixture for Paper-Cutting Knives

The engravings, Figs. 113, 114 and 115, represents a fixture for grinding knives used in machines for cutting paper and paste-

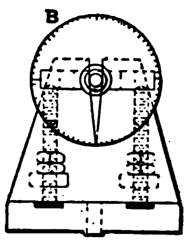


Fig. 113. — Grinding Fixture for Paper-cutting Knives.

board. Having several of these knives, ranging from 2 to 5 feet in length and 5 inches in width, and finding it inconvenient to

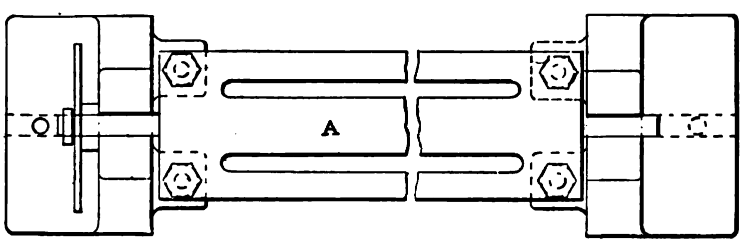


Fig. 114. — Grinding Fixture for Paper-cutting Knives.

block up with a wooden frame and wedges set on the table of the grinder, the following method was resorted to:

Referring to Figs. 113, 114 and 115, *A* represents a gray-iron plate having a bearing at each end and two slots milled nearly

the full length of the casting. The knife is strapped to the plate by means of bolts in these slots, the edge of the knife slightly overhanging the edge of the plate. *B* is a graduated gray-iron disk with a hub formed at the end of the plate, running through the hole bored through the disk. The supports are gray-iron castings, the lugs shown being tapped for the set-screws which adjust the plate *A* to the required angle for the work. The pointer for reading this angle on the disk is pinned to the hub or trunnion at one end of *A*.

The angle to which the plate is set with the horizontal ranges from 12 to 20 degrees, and may be read off directly on the disk. The four set-screws provide all necessary adjustments, as movement sidewise is unnecessary, as the drilled holes in the knife coincide exactly with the slots in the plate. The grinder in question is one used for cylindrical work, and has longitudinal and cross feeds. When the supports *A* are bolted to the table and the knife strapped to the plate, adjustment is speedily secured and the job quickly and accurately accomplished. Should any vibration occur in the plate, a small jack-screw may be placed under it.

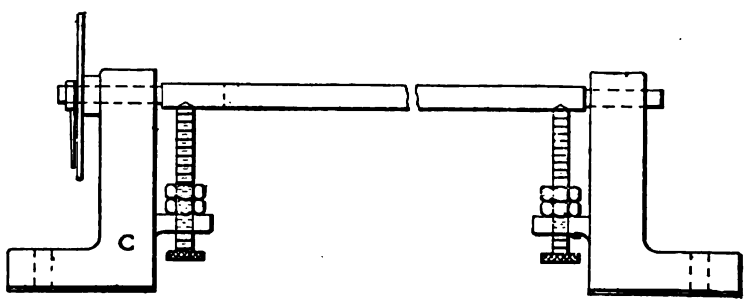


FIG. 115. — Grinding Fixture for Paper-cutting Knives.

FIXTURE FOR GRINDING ROTARY PLANER CUTTERS

Figures 116 and 117 illustrate a rig for grinding cutter heads for rotary planers, making use of a Hisey-Wolf portable grinder. In a certain shop there are three of these rotary planers in use with 60 tools each. It formerly took from 3½ to 4 hours weekly to change tools alone for grinding. With this rig the tools are ground in place in 30 minutes and they are ground perfectly,

which was not the case by any means formerly. They run in the machine for about three months without requiring changing.

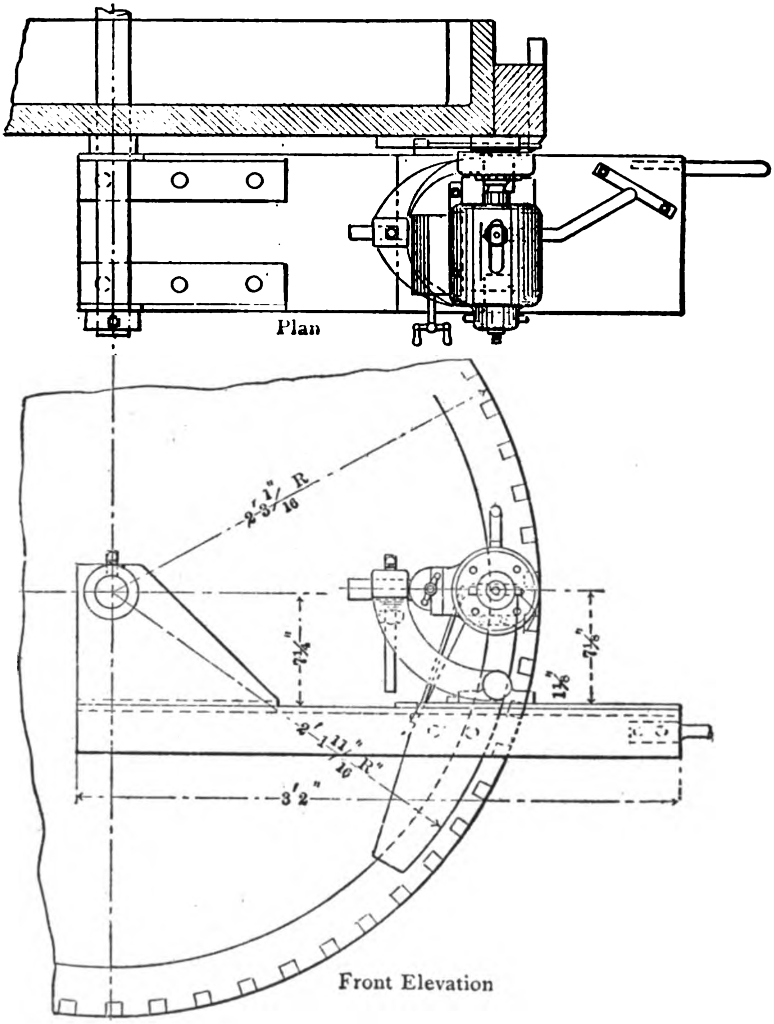


FIG. 116. — Fixture for Grinding Rotary Planer Cutters.

The illustrations of this grinding fixture are sufficiently plain to make a detailed description of it unnecessary. Full details together with all dimensions are included in the illustrations.

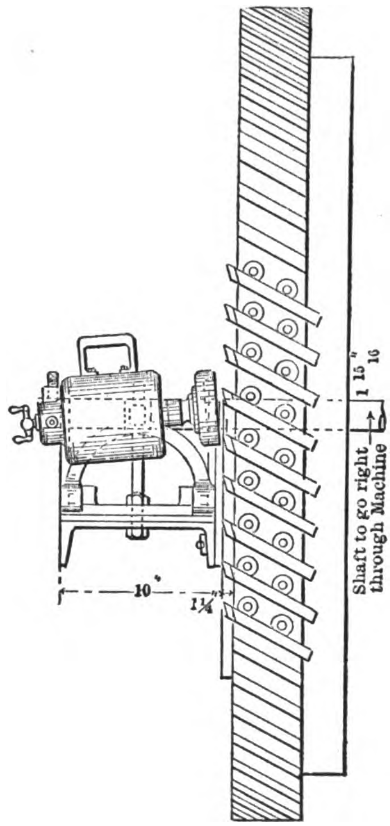


FIG. 117. — Grinding Rotary Planer Cutters.

GRINDING FIXTURES FOR GAS ENGINE CYLINDERS

We have found, and suppose every one has who has ever had much to do with gas engines, that the finish and truth of the cylinder bore, piston and rings should be the very best possible. To attain this perfection the two grinding rigs illustrated in Figs. 118 and 119 were designed and built to grind the bore of cylinders. Fig. 118 shows a rig for the lathe that does the work well. The drawing is not to scale, but shows the idea, and any machinist can work out the details. *A* is a chuck which centers and holds one end of the cylinder, the other being end-centered in the revolving steady rest *B*. *C* is the revolving part of the rest

carrying the four jaws *D*, which center and hold that end of the cylinder. *E* is a gray-iron casting that bolts to the cross-slide of the carriage and has a gib under the bar *F* bolted to the carriage. When set for the cut the gib can be set up, making all rigid.

The casting *E* has through its center, running in bearings, a shaft carrying an emery, corundum or carborundum wheel at one end and a driving pulley at the other. *G* is the end of a cast-iron frame of the same pattern as *E*. The end is counterbored to

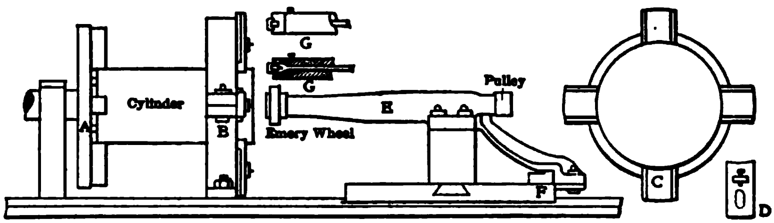


FIG. 118. — Grinding Fixture for Gas Engine Cylinders.

receive a machinery steel piece slotted across the face to receive a square piece of tool steel. A set-screw holds the end piece from turning and a long steel bolt with a hole at one end and a nut at the other holds the cutting tool secured. This is used for boring.

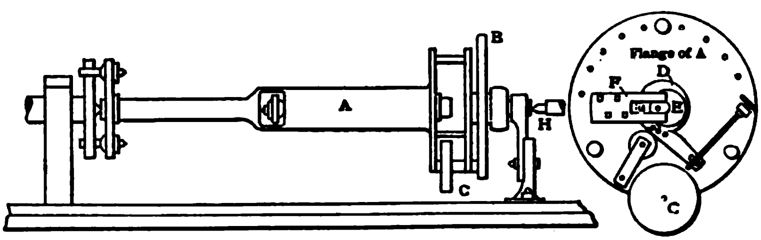


FIG. 119. — Grinding Fixture for Gas Engine Cylinders.

Figure 119 shows a grinding bar to use between centers of the lathe when the work is secured to the carriage and bored with a boring bar. It consists mainly of a gray-iron casting *A* with a driver fitted to it; the larger part is cored out and has a flange at the end. The core cutting through one side in the middle, as shown, allows the grinding wheel to project. This casting is bored and the flange finished all over and then secured by three solid studs to another flange carrying a short shaft. Of course

this short shaft should be recentered and finished in perfect alinement after the studs are fitted. This shaft carries a pulley running loose, to which is secured an internal gear *B*, which drives a rawhide pinion secured to the shaft of pulley *C*, a belt from which drives the grinding wheel. A casting *D* is turned to fit nicely the bore in *A*. *D* is bored eccentrically to receive a casting *E*, which carries in proper bearings the grinding wheel arbor. These castings are made in skeleton form to save weight as much as possible. A steel piece *F* is fastened to the flange and in it slides a steel piece *G* that fits into a counterbore in *E*, the grinding arbor passing through it. A tangent screw is provided for fine adjustment. The construction and use of it are too obvious to need further description. A bearing *H* is secured to the bed of the lathe and adjusted to relieve the center of any belt pull.

Grinder and Fixtures for Finishing Piston Rings

A new method of finishing piston rings is illustrated in Figs. 120, 121 and 122. The method consists of grinding the periphery of a ring under essentially the same conditions as affect it when it is in the cylinder of the engine, but before describing it fully it will be well to briefly review the conditions affecting the manufacture of piston rings as generally followed.

Every mechanic knows that a ring that is turned larger than the bore of the cylinder, whether it be of uniform thickness, bored eccentric or cast to a theoretical tension curve on the inside surface will not have a uniform tension or bearing on the surface of the cylinder bore until it has been filed or scraped to fit, or let run until it wears itself to a bearing. That the last named method is not good practice is quite obvious. The efficiency of a gas engine to a large extent depends upon the compression it is possible to obtain, and if the rings have imperfect bearing, the efficiency under the first working test must be below the standard. Moreover, the leak may never take up entirely on account of the destructive scoring effect of the escaping gases on the cylinder walls. To file and scrape a piston ring to a good bearing is a laborious and expensive job, and is one that is usually commercially impracticable on account of the keen competition in this field of manufacture.

One method of obtaining an approximately close fit is to

spring the ring down nearly to the cylinder diameter and clamp it between collars or flanges; then having removed the form a light cut is taken over the periphery. This method is a decided improvement over the fitting-by-hand method but it is by no

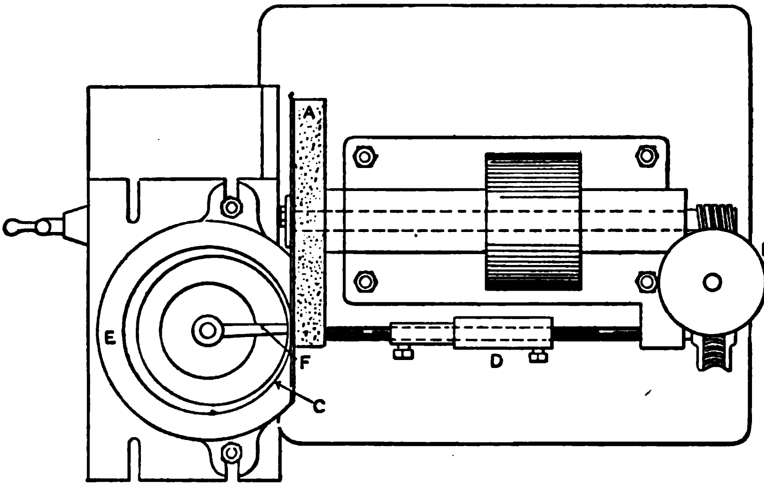


FIG. 120. — Grinding Piston Rings.

means a perfect job, for it will leak, the simple reason being that taking a cut over the surface, which necessarily takes off more stock in some places than in others, changes the tension of the

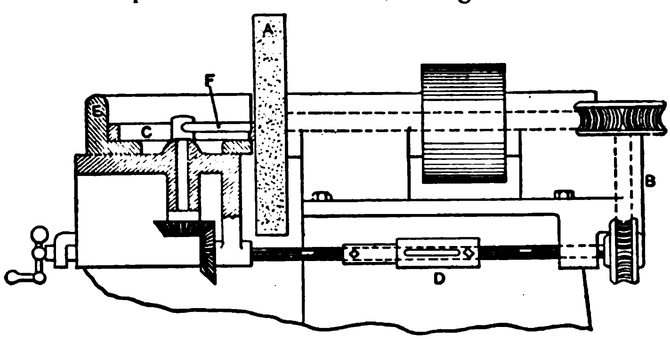


FIG. 121. — Grinder for Piston Rings.

ring and the distribution of the metal so that as soon as the clamp collars are removed it alters shape. To prove this put it in the cylinder, when daylight will invariably be seen between the ring and the cylinder bore. Or, a better test is to spring it down to

the size it was last turned to, and after removing the form to test it in a universal grinding machine. The ring will be found to "run out" no matter how many times the operation is repeated. In a series of experiments along these lines on 6-inch rings they were found to run out when the operation was repeated not less than twelve times. Of course the error diminished at every grinding, but the principle remained the same.

Some manufacturers make their piston rings eccentric with the inside bore, which is left rough for cheapness of production and also to get the benefit of the scale remaining inside; the scale improves the elasticity of the ring and lessens the liability of

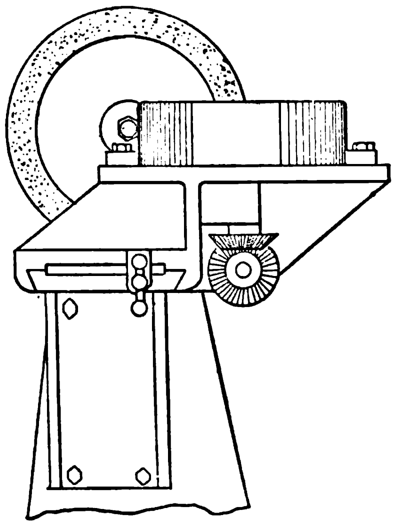


FIG. 122. — Grinder for Piston Rings.

breaking or distortion when sprung over a solid piston. This method does not produce a perfect bearing ring, although some of the evils of the turned eccentric ring, finished all over, are undoubtedly made less thereby.

After going over the various methods of manufacture the conclusion was reached that there is only one practically perfect method of finishing piston rings, and that is to grind them under the same conditions that they are subjected to in working, and the machine shown in Figs. 120, 121 and 122 was designed with this object in view. It consists of a frame carrying an emery wheel *A* and a form *E*, in the center of which latter is a revolving finger

F driven by suitable worm reduction gearing *B* from the emery wheel spindle. The form *E* is bored smaller than the diameter of the ring to be ground, being of the same diameter as the cylinder, to which it corresponds; various sizes are provided to suit the sizes of the rings to be ground. The table carrying *E* is adjustable relative to the emery wheel, the driving gear shaft having a telescopic sleeve *D*. One side of the form is cut off tangentially so that about $\frac{1}{8}$ inch of, say, a 5-inch ring is exposed to the emery wheel. The ring, of the type shown in Fig. 123, is sprung into the form with the finger *F* engaged in the cut. The finger slowly revolves the ring while the grinding wheel removes the high spots and these only. As the grinding proceeds the ring changes shape, conforming more and more closely to the form until it reaches a practically perfect bearing therein. It makes no

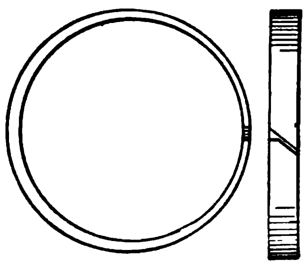


FIG. 123. — The Piston Ring.

difference what the character of the material composing a ring is, its width, hardness or defects, such as blowholes, spongy spots, etc.; it will grind to an exact bearing in any case because the ring is free to adjust itself to the changing condition due to the removal of the high spots. Naturally, therefore, we come to the conclusion that this is a sure way of eliminating the one serious trouble in the manufacture of gas engines. A piston ring finish that will get a "stay-over-night" compression, is produced in this machine easily, and the machine is adapted to a wide range of sizes of rings. It is not confined, of course, to the production of gas engine piston rings, but any kind or style of piston rings required may be produced equally well. This machine makes it possible to produce chilled piston rings, and, in fact was designed with this object in view.

When piston rings are to be ground in place in a solid piston

so as to avoid distortion incident to springing them into the grooves, the form *E* is made deep enough to receive the whole piston and the driving finger *F* is removed. The piston is revolved by suitable pins which drive both the piston and its rings, the piston being drilled to receive the driving pins. This method of finishing piston rings is patented by Warren Chambers, of Toronto, Ontario.

A Combination Grinding and Drilling Fixture

The illustrations, Figs. 124 and 125, show a little fixture originally intended for grinding only, but eventually other spindles were made for holding drills, etc. Later on several of the tools were made complete with spindles, so that it was not necessary

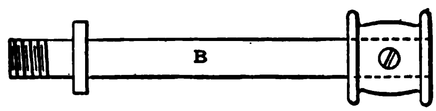


Fig. 124. — Fixture for Grinding and Drilling.

to change over. The body of gray iron is shown at *A*; it was bored roughly about $\frac{7}{8}$ inch. The spindle *B* was made of tool steel and the straight part was ground $\frac{1}{2}$ inch diameter. The casting *A* was made so that the center of the hole for the spindle was the same hight as the centers of the lathe on which it was to be used.

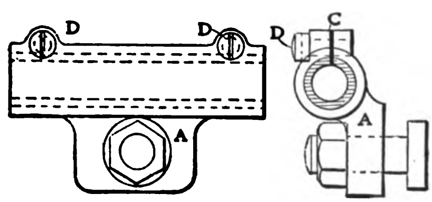


Fig. 125. — Fixture for Grinding and Drilling.

After the spindle was made it was slipped through the hole in *A*, mounted on the centers and preparations made for the babbitting of the bearing, the whole thing, spindle and all, being heated with gas. After the babbitt was set the screws *D* were fitted, the $\frac{1}{16}$-inch saw slot *C* was run the whole length of *A*, and holes were drilled and tapped for small oil cups. The slot *C* was filled with a piece of raw-hide belt lace to keep dirt out. On the

later spindles ball thrusts were put at each end. One spindle was hollow and fitted with draw-in chucks. The first one was in nearly constant use for about five years at various speeds between one and ten thousand revolutions per minute. It gave no trouble and did not require either a new spindle or rebabbitting.

Gland Flange Grinding Fixture

The gland flange grinding fixture shown in Fig. 126 is a well tried, simple attachment to an ordinary emery wheel grinder. The fixture has been used for a long time in a large pump manufacturing establishment, and meets all requirements. The gray-iron standards *A* are bored to receive rock shaft *B*, and between standards *A* are two arms parallel to each other that are bored at their ends to receive the gland holding shaft *C*. The drawing shows a gland in position to be operated upon. Keyed upon the rock shaft is a third arm at right angles to and located between the work-holding shaft arms. This third arm is connected by a split-end tie-rod to a foot-lever. It will be noticed that the foot-lever has a bearing back from the tie-rod, and when the foot pressure is applied to the outer end of the foot-lever the work-holding shaft is moved toward the emery wheel, indicated by dotted lines. It will be also noticed that the foot-lever has a weight at its inner end sufficiently large to cause the vibrating work-holding shaft *C* to recede from the emery wheel the instant the foot has been taken from the foot-lever, and the removal of the gland is accomplished in safety. A hand-wheel of liberal size is fastened between the arms upon the work-holding shaft to furnish means for the operator to turn the shaft and gland while the latter is being ground. The work-holding shaft has a collar against which the gland is forced by means of a key, this being a quick way of releasing the work from the shaft. At *D* are filling-in washers, as the lengths of glands vary. Bushes are furnished to suit the work-holding shaft and the various sizes of holes in the glands.

It will be noticed that two stop-collars allow an end movement to the work-holding shaft; that is so that the wheel may have an equal amount of wear over its entire surface. The movement of the work-holding shaft being at the will of the operator allows

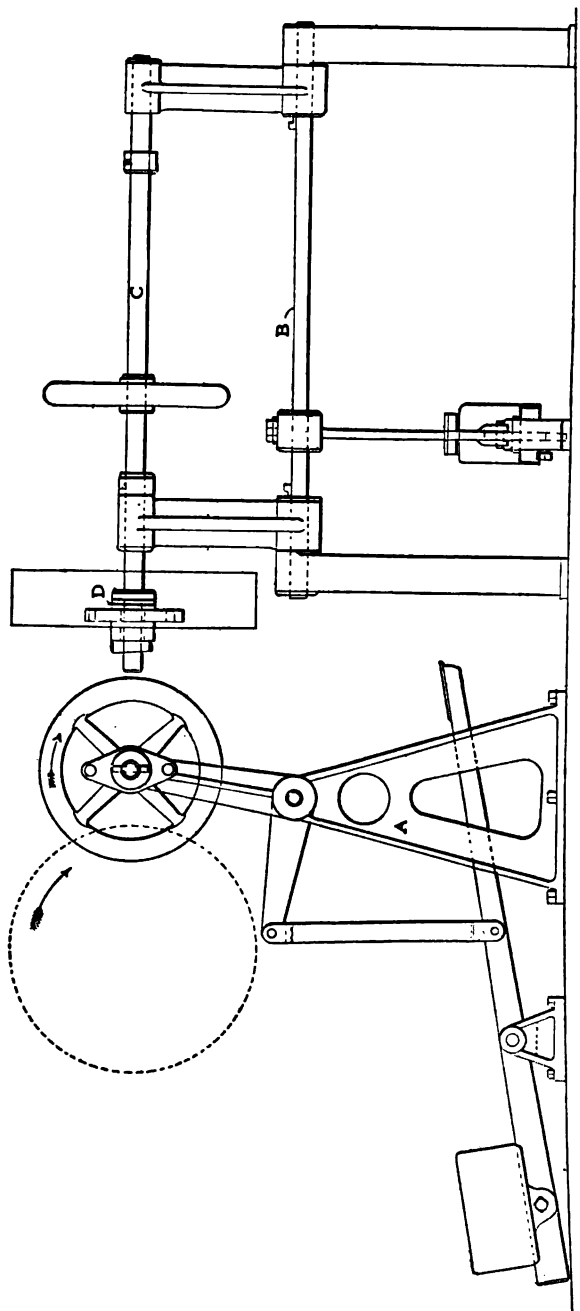


Fig. 126. — Gland Flange Grinding Fixture.

him to go rapidly over the smooth surface of the casting or linger upon the rough spots, such as unchipped gates, etc.

The mechanical talent required to operate this fixture need not be of a very high order, and after a few moments of instructions a "raw recruit" can handle the work quite satisfactorily.

Fixture for Grinding Boring Bars and Counterbore Cutters

It is difficult to grind boring bar and counterbore cutters and have the lips of the cutting surfaces come anyway near correct. Usually the variation of the lips on large cutters will be so great

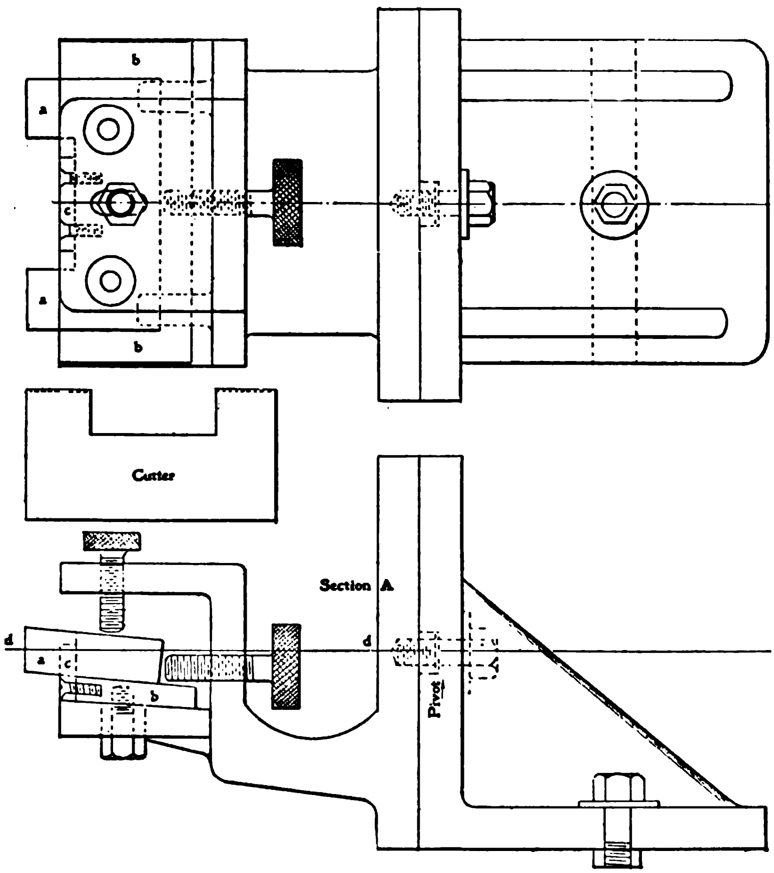


Fig. 127. — Fixture for Grinding Boring Bars and Counterbore Cutters.

if ground by hand as to strain the boring bar. To overcome the difficulty a fixture was designed as illustrated in Fig. 127, which will enable both lips of the cutter to be ground at one setting. When the first lip is ground loosen the pivot bolt, then turn section *A* half-way round and the other lip will be in position.

At *A* is a cutter set for grinding, *b* is a taper slide with a detachable stop *c*. Stop *c* should be made of tool steel hardened and in three or four sizes, to correspond with the width of the cutters. It is essential that the center of the cutting edge should be in line with the pivot, as illustrated at center line *d*, which can easily be adjusted with the taper slide. This fixture can be adapted to almost any grinder. The best results are obtained by the use of a cup emery wheel.

A Grinding Fixture for Bronze Washers

The simple little fixture shown complete in Fig. 128 was designed to hold, for grinding, the bronze washers shown at *X*. These washers were to be face ground on both sides, and the usual

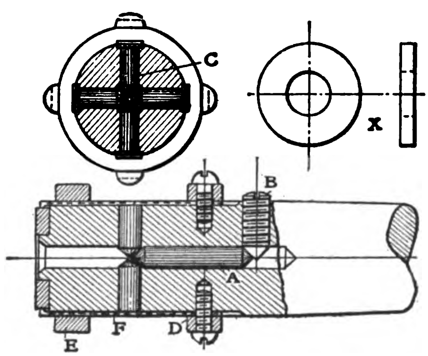


Fig. 128. — Fixture for Grinding Bronze Washers.

form of expanding chuck was found wholly inadequate. This fixture comprises an arbor made with a suitable taper to fit the head spindle of a No. 3 Landis universal grinder, on which the work was to be done.

The center of the arbor is drilled out and fitted with a pin *A*, having a cone point at each end, the back part being about 100 degrees, included angle. The back end of *A* is fitted to a headless set-screw *B* having a cone point of about 80 degrees. The

front end *A* is pointed to 80 degrees to fit the four radial pins *C* having 100 degrees point, and it will be readily understood that inward movement of the set-screw *B* expands the four radial pins against four springs *F*. These springs are held in place by two collars *D* and *E*, fastened to the arbor by screws. The collar *E* is provided with four slots, relieved toward the inner face so as to allow the springs free expansion under pressure of the radial pins.

The springs are provided at their outer ends with lips, these being formed to fit the circumference of the washers. The end of the arbor is turned to provide a center for the washers. The latter come pretty true to size, so only a small movement of the spring jaws is necessary.

Index Grinding a Hard Steel Ratchet

The ratchet shown in Fig. 129 is $1\frac{3}{4}$ inches diameter and about $\frac{1}{16}$ inch thick, with 19 teeth, the hole being about 1 inch diameter. Two of these ratchets were required of hardened tool steel. They were got out, leaving a little stock all over, and sent to what was thought to be a well-appointed shop for this kind of work, with the request that they harden and temper them, grind the sides flat and the holes to fit a piece sent with the job, grind the outside diameter to size, and then index grind the teeth on their radial faces. The thickness was not particular, but the sides were to be flat and parallel. One ratchet contained one dowel-pin hole, while the other ratchet contained two dowel-pin holes, $\frac{1}{38}$ of a turn apart. The dowel-pin was to be in one of these latter holes while both ratchets were index ground, and in the other when the ratchets were in use, thus giving, in effect, a 38-tooth ratchet with teeth staggered. The concern to whom the job was sent did not seem particularly anxious to do the index grinding, so that part was done after the rest of the work was completed by the people who roughed out the ratchets.

This is how the job was done. Fig. 130 shows a plug of brass, the part *a* being an easy fit in the holes in the ratchets, while *b* is about $\frac{1}{8}$ inch longer in diameter. Both ratchets were placed on this plug, the dowel-pin inserted to bring the teeth to tally, and the tooth nearest the dowel-pin hole (tooth *A*) was ground freehand on the emery grinder, enough being taken off to make

sure that no stock would have to be "put on" the other teeth to make the indexing correct. The ratchets were then separated and each of the remaining teeth ground just enough to make them bright, and bring the distance off center the same for all. The teeth were not quite radial, but were slightly hooking, being ground .093 inch off center. Fig. 129 shows how this was done. the straight-edge *c* was clamped to the table of the emery grinder, parallel to the face of disk *d*, and distant from it .968 inch. The

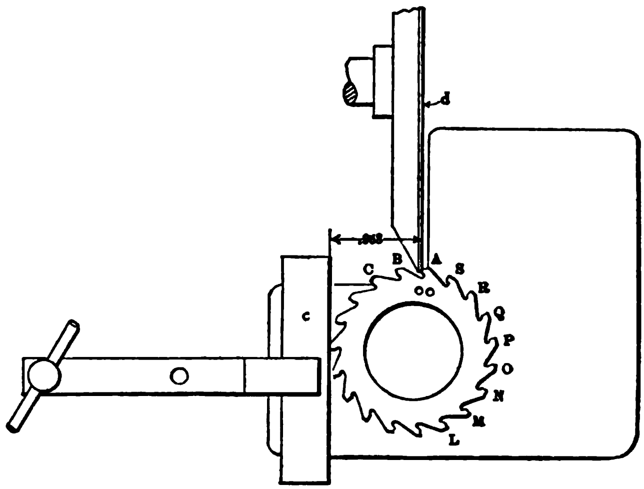


FIG. 129. — Ratchet to be Ground and Method Involved.

ratchet was laid flat on the grinder table and pressed lightly against *c* while each tooth was being ground, to get the teeth all the same distance off center. Of course a slight error would show here, as the number of teeth was not an exact multiple of 4, but

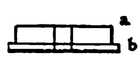


FIG. 130. — Plug of Brass.

this did not matter, as the main thing was to get all the teeth equally hooking, and approximately .093 inch off center. The grinding was done with No. 1½ emery cloth stuck on the cast-iron disk *d* with beeswax.

The next thing to do was to test the teeth to find out how much was to be taken off each to make the indexing exact within

the limits required. This was done as shown in Fig. 131. The plate *f* is ⅛-inch sheet brass taken from scrap box, and having a small pin *g* driven in tightly, while the plug shown in Fig. 126 is screwed to *f* in such a manner that a ratchet could be dropped over the plug and rotated gently until one of its tooth faces was brought in contact with pin *g*. Plate *f* and also an indicator were firmly clamped near one corner of the bench surface plate, so that when a tooth of the ratchet was in contact with the bell crank arm of the indicator, by lifting the ratchet up a little and turning it slightly before dropping again, each tooth could be brought in succession against the arm of the indicator and a reading

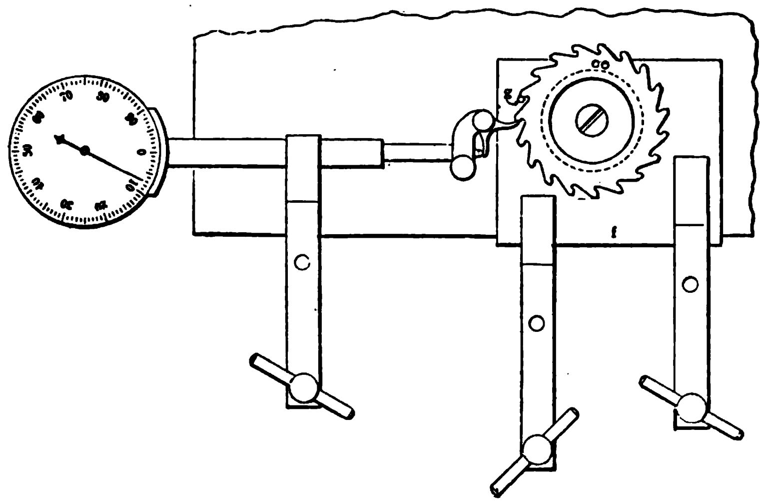


FIG. 131. — Testing Teeth.

taken. Of course, if the indexing of the ratchet were exact, the indicator would read alike at each tooth, but if errors existed, the indicator readings would vary with the amount of and direction of the errors. This indicator has a dial graduated to read to .001 inch, but with a watchmaker's glass tenths of a division could be estimated.

The letters opposite the teeth in Fig. 130 are simply for reference, to identify the teeth in the table of errors, and to tell one which tooth he was working on during the grinding process. The reading of the indicator was influenced not only by the error of the tooth with which it was in contact, but also by the tooth

in contact with pin *g*, Fig. 131, so that a reading could not be considered as belonging to one tooth, but as belonging to the interval between the two teeth in contact with the indicator and pin *g* respectively, at the time the reading was taken.

Teeth.	Indicator Readings.	Interval Errors.	Tooth Errors.
A			.0000
	.0139	+ .0067	
B			.0067
	.0057	— .0015	
C			.0052
	.0070	— .0002	
D			.0050
	.0088	+ .0016	
E			.0066
	.0088	+ .0016	
F			.0082
	.0049	— .0023	
G			.0059
	.0075	+ .0003	
H			.0062
	.0084	+ .0012	
I			.0074
	.0060	— .0012	
J			0062
	.0080	+ .0008	
K			.0070
	.0057	— .0015	
L			.0055
	.0075	+ .0003	
M			.0058
	.0082	+ .0010	
N			.0068
	.0054	— .0018	
O			.0050
	.0116	+ .0044	
P			.0094
	.0030	— .0042	
Q			.0052
	.0075	+ .0003	
R			.0055
	.0083	+ .0011	
S			.0066
	.0008	— .0064	
A			.0002

19) .1370

.0072 = mean indicator reading.

FIG. 132. — Readings and Errors of Ratchet before Grinding.

The table, Fig. 132, shows in its first column the 19 letters representing the ratchet teeth, the second column showing the indicator readings. Tooth *A* is repeated at the bottom of the table, so as to get the 19 intervals complete. The mean of the 19

indicator readings is .0072, which is what the indicator would have read each time had no errors existed in the indexing of the ratchet. This mean was algebraically subtracted from each of the 19 readings, and the results placed in the third column as "interval errors," marked plus where the interval between two consecutive teeth was too great, and minus where the interval was too small. As the error of each tooth is the algebraic sum of the error of the interval between these two teeth, we thus have a means of obtaining the figures in the fourth column, which represents the "tooth errors," or the amount to be ground off. As tooth *A* is the starting point, it has no error. The error of *B* is the same as the error of interval between *A* and *B*, or .0067 inch. Error of *C* is equal to the sum of + .0067 and − .0015, or + .0052 inch. Error of *D* is equal to the sum of + .0052 and − .0002, or .0050 inch, and so on down to the bottom of the table, where *A* is shown to have an error of .0002 inch, while at the start *A* was supposed to have no error. This arises from the inexact division in obtaining the mean, the remainder there being .0002 which appears as an apparent error after getting around to the starting point. However, it could be easily and safely neglected, as it was very much smaller than the errors of workmanship that would creep in with the improvised methods used on this job.

After having tabulated the tooth errors, the next step was to grind off each tooth just the amount that the table showed to be its error. This was done by putting a pencil mark on the particular tooth to be ground, placing the ratchet in the testing ring so that the marked tooth was in contact with the indicator, and taking a reading. From this reading was subtracted the tabulated error for that particular tooth, which gave the reading the indicator ought to show after that tooth was fully corrected. Of course, after starting to correct a tooth, it had to be ground to a finish before any other tooth was commenced on. This method necessitated frequent alterations between grinding and testing, the two operations being practically carried on together. On the other hand, the wear of the grinding wheel would have little effect on the accuracy of the indicating.

The table shows the errors of the teeth in the ratchet having two dowel pin holes, but a similar table was made for the other ratchet, and it was corrected in precisely the same way, after which both ratchets were tested separately, and new tables of

errors were formed for each to test the results, only these new tables showed very much smaller errors. Some of the teeth had too much to grind off, the worst one in this respect having a final error of .0009 inch, while some teeth had too much stock left on them, the greatest final error of this kind being .0008 inch. Half the sum of these two errors, or .00085 inch, represents the maximum error of the 38-tooth ratchet when compared with a theoretically exact ratchet, where errors are allowed to exist in each direction. If errors are allowed in only one direction when comparing the work with the ideal ratchet, then the maximum error would be .0017 inch.

SECTION IV

THE HARDENING AND TEMPERING OF INTERCHANGEABLE TOOL STEEL PARTS OF DELICATE STRUCTURE WHICH REQUIRE TO BE GROUND AND LAPPED AFTERWARD.

Trouble Experienced and Results Desired

A machine manufacturing concern in the East, doing a business of $5,000,000 annually, had been trying unsuccessfully for fifteen years to produce certain perfectly hardened ground and lapped interchangeable tools steel parts at a piofit. Large sums of money were expended; all theories and processes and known methods were tried at great expense, but without success. As a last resort we were called in by the company in the capacity of expert in steel treatment and interchangeable manufacturing, and were told to go ahead and produce perfectly hardened parts which would not have to be straightened afterwards, and which could be produced at a good profit. What we found upon arrival on the ground, and how we succeeded in producing perfectly hardened parts which *did not* require to be straightened afterwards, may be learned, from the following particulars which are given to enable establishments and individuals having similar difficulties to find herein something that will help them to locate the trouble and remedy it without resorting to expensive consultation.

The Work to be Hardened

Figure 133 illustrates the shape, size and frailness of the parts to be hardened. They are shown full size. Those familiar with the difficulties encountered in producing such work will concede that the heating and quenching of pieces of such shape, so that they will come through the process straight and true, admit of

being ground to within .0005 inch limit of variation on both sides and edges, without previous straightening are certainly difficult to perform. The following is the report made by us on the hardening process, the cost of which was 50 cents per hundred pieces when we were called in:

Steel Used for the Wedges

"*Mr. Collenos, Superintendent Millennium Machine Company*:

"I find that the grade of steel used for the wedge slides is of the cold rolled variety — that is, steel that has been subjected to a finishing operation of rolling after it has become comparatively cold. I have also learned that formerly hot rolled and

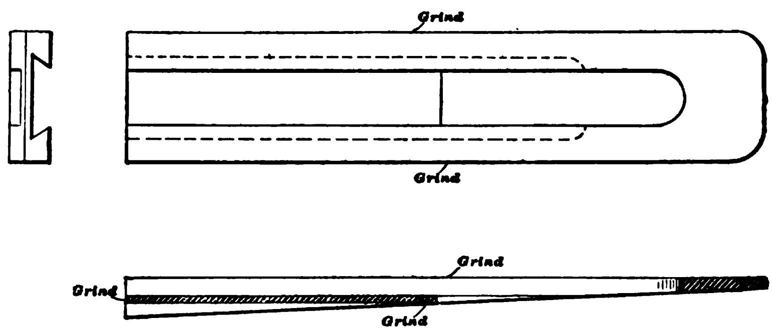


Fig. 133. — The Wedge Slide to Hardened, Ground and Lapped.

finished steel was used, but that the cold rolled variety was substituted in its stead because of variations in thickness, width, etc., existing in the other stock.

"The use of this cold rolled material is to be condemned as not in accord with the most advanced practice, and it should be discontinued. No difficulty should be experienced in procuring hot rolled and finished steel in uniform sizes. In any event the use of cold rolled stock is decidedly bad practice, as it is a grade of steel which is in no way suitable for articles as accurate as the wedge slides are required to be.

"My reasons for advising this change in the variety of steel are: All cold rolled or finished carbon steels, even those of the lowest carbon percentages, are unsuitable for the making of articles which are required to be subjected to very accurate grinding, lapping, and other operations after being hardened

and tempered. This defect in the steel comes about through the methods employed in its manufacture; The steel being almost cold when it is given the final rolling or sizing, an outer shell or skin forms over all sides of it. This shell being hard and brittle, as compared with the core of the bar or strip, the ensuing results are such that when the steel is sent through the first few roughing operations in the machines, which, in the case of the wedge slides, are milling ones, it buckles up and springs out of shape under the cutting tools. Then again, when the parts made of such steel are subjected to a high heat, and are afterwards hardened, they change shape again, some stretching and warping, others shrinking, so that it becomes well-nigh impossible to control the shapes of the parts.

"Hot Rolled and Finished Steel: Its Value

"The hot rolled and finished steel is the best variety to use because the process of hot rolling has an effect on the metal somewhat similar to that imparted to carbon steels through forging or annealing. Thus such steel comes to the machining operations in an ideal, and, as it were, a perfectly free state, the entire bulk being uniform, and the outer skin of the same ductility as the inner core. Therefore, all tendencies of the parts to spring or buckle under the cutting tools immediately upon the surface being removed, is eliminated.

"Effects of Proper Finishing in Manufacture of High Carbon Steels

"As an instance of the effects of proper finishing in the manufacture of carbon steels, I might mention for your information that one of the best known file companies in this country experienced great difficulty and many setbacks in their efforts to duplicate 'Swiss' files, particularly in the hardening and tempering operations of the very small files so that they would come through the process straight and true. As the heat treatment for a delicate and tapered file and that for the wedge slide manufactured by this company should be similar the comparison is consistent.

"An expert was called in by the file people to suggest some-

thing to overcome the difficulty; and he found that the trouble rested principally in the manufacture of the raw material. The steel producers, therefore, were prevailed upon to subject the bars of raw stock to a hot finishing operation, which consisted of squeezing and compressing the hot bars in a concluding operation. Upon the steel so treated being used, and subsequently worked up into files and then hardened and tempered, the ensuing results were indeed gratifying, no trouble at all being experienced in producing perfectly straight and true files. Therefore, your expert advises, as a precaution to insure the entire elimination of all tendencies of the steel to warp — which troublesome conditions *do* not exist — that the manufactures of the '*Z temper Mars Steel,*' which is used for the wedge slides, be requested to submit the metal to a hot finishing operation of squeezing or compressing, which will have the same effect as a forging operation would, setting the grain of the metal firm, giving a uniform ductility and density of structure, as well as an even arrangement of molecules throughout the entire bar.

"The procuring of steel which has been treated as outlined in the foregoing should be arranged for without materially increasing the present cost of the raw material.

"Hardening of Wedge Slides

"The greatest reduction in the present production cost of the wedge slides can only be directly effected by means of improved methods whose installation must follow the perfecting of the hardening and tempering process.

"To substantiate the foregoing contention, it is only necessary for one familiar with the practical treatment of steel to examine carefully into the methods and operations which precede the heat treatment, and also those which follow it. At present the amount of stock left to be removed from the wedge slides by grinding is excessive when we take into consideration the frail structure of the articles produced. Another thing, the means in present use for hardening the slides — heating in a muffle and then clamping them between a pair of water-jacketed dies until cold — produces results in the steel that combine to destroy any permanency of accuracy, no matter how carefully the succeeding mechanical operations are performed. As a practical illustration

of what occurs at present, and the ruinous effects afterwards, the following should be convincing.

"Effects of High Heat Treatment on Carbon Steel

"Steel of the carbon percentage used for the slides, by reason of its structure and composition, when subjected to high heat treatment and then quenched, rearranges itself, as it were, from skin to skin. That is, the molecules refine, and assume closer and more regular positions with regard to each other, than those occupied previous to the heat treatment.

"Now, costly practical experience has demonstrated to me, beyond the shadow of a doubt, that this rearrangement of the molecules must be allowed to remain permanent, if accurate and uniform interchangeability is to be attained at the minimum of cost and labor in the finished articles through mechanical means. With the means at present in use for the heat treatment — a muffle furnace and a pair of water-jacketed dies for cooling — the very crudeness of it all suffices to prevent the attainment of uniform results. Crooked and warped edges, stretched and shrunken sections, burned spots, alternating brittle and soft spots, thick black scale, caused by contact while red-hot with an oxidizing atmosphere, as well as unequal heating and cooling — all these conditions exist in the wedges treated by the methods at present in use.

"Effects of Straightening, Hammering and Twisting on Small Hardened Parts

"If these results were not sufficiently harmful to destroy whatever permanent qualities the steel possessed, immediately after the operation of hardening, the wedge slides are subjected to even more harmful operations, which totally destroy the regular arrangement of the molecules, and the uniform structure of the entire article, positively interdicting the attainment of interchangeability in the finished parts. These operations may be enumerated as follows: straightening, hammering, stretching and twisting; thus all machine operations which follow are of no avail toward producing duplicate parts, because the fundamental structure upon which the permanency and accuracy of all results depend, has been totally destroyed.

"Cost of Operations Necessary through Improper Hardening

"Now, in order to produce parts within your required limit of variation, hand work is entirely depended upon, so that when the articles are at length finished all evidence of machine operations has been eradicated by the file in the hands of the fitter and adjuster. You will now understand why I advise the perfecting of the hardening process at as early a date as possible; for then, and only then, will you be in a position to commence the manufacture of perfectly interchangeable parts in the wedge slide department. The eighteen operations which precede that of hardening and tempering cost $2.08 per 100 wedge slides. The hardening and tempering operations, and the fourteen others which follow them, cost $9.82 per 100 wedge slides. Therefore, the fact is clearly evident that if much reduction in the productive cost is to be effected, it must come to pass through the elimination or simplifying of operations which follow those of hardening and tempering."

The Automatic Hardening Machine for Wedge Slides

After the acceptance and approval of the report, through our endeavors an automatic heating machine was designed and constructed by the American Gas Furnace Company, New York, and installed in the above-mentioned company's wedge slide department. This machine is shown clearly in Figs. 134 and 135. The wedges were hung on fingers which were fastened to a slowly moving chain, and traveled down through an eight-burner muffle and thence into a bath of whale oil. The machine's capacity was over 5000 wedge slides per day, and the work was performed at a labor cost of 2 cents per hundred, as against a previous cost of 50 cents per hundred. And the parts came through the operation free from scale, uniformly hardened and straight. As the output per year of these parts was something in excess of 150,000, the saving on the hardening alone amounted to approximately $750.

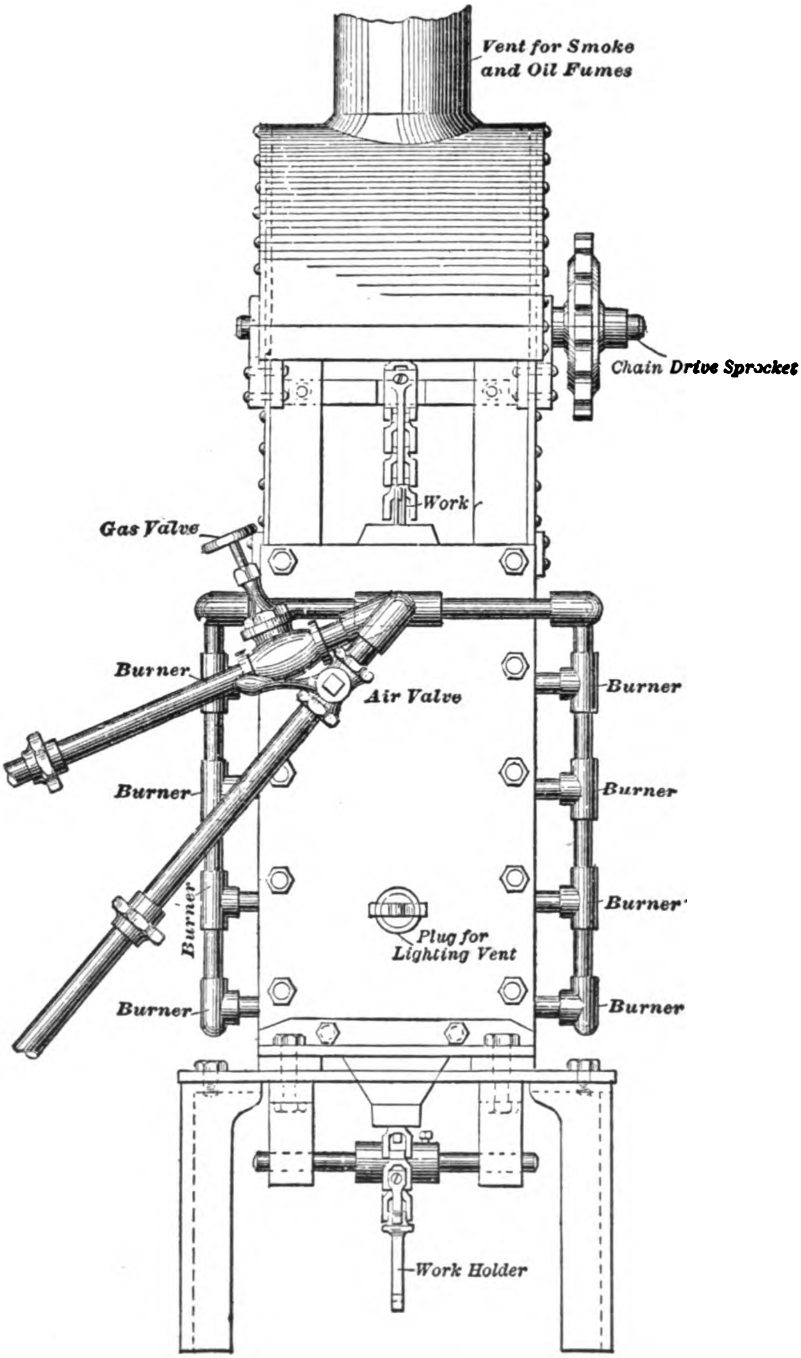


FIG. 134. — Automatic Hardening Machine for Wedge Slides.

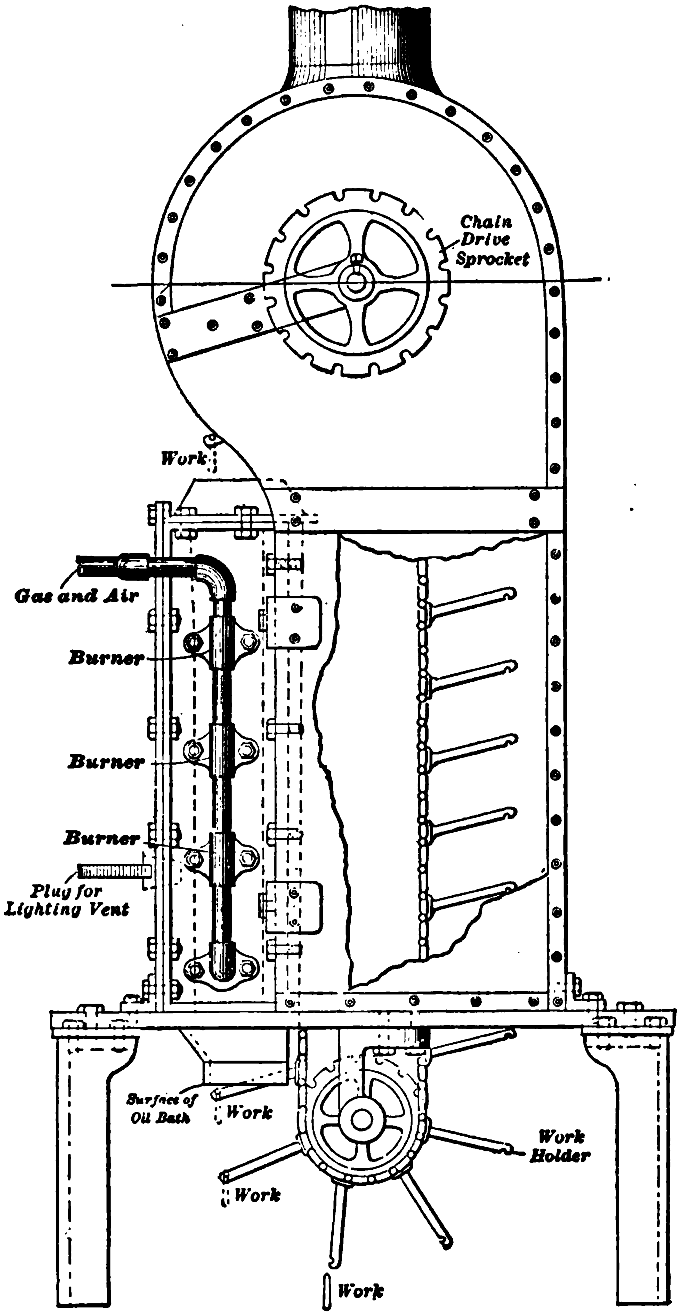


FIG. 135. — Automatic Hardening Machine for Wedge Slides.

The Improved Quenching Tank for Hardening Machine

The arrangement we designed and installed beneath the automatic heating machine for the quenching and hardening of the work is illustrated in Fig. 136. A short description together with the main specifications will enable readers to understand it and also to adapt it for similar work.

A is the outer water tank; *B*, the oil tank; the pipe indicated at *H* is the coil inlets for the hot oil; and *D* the discharge pipe for

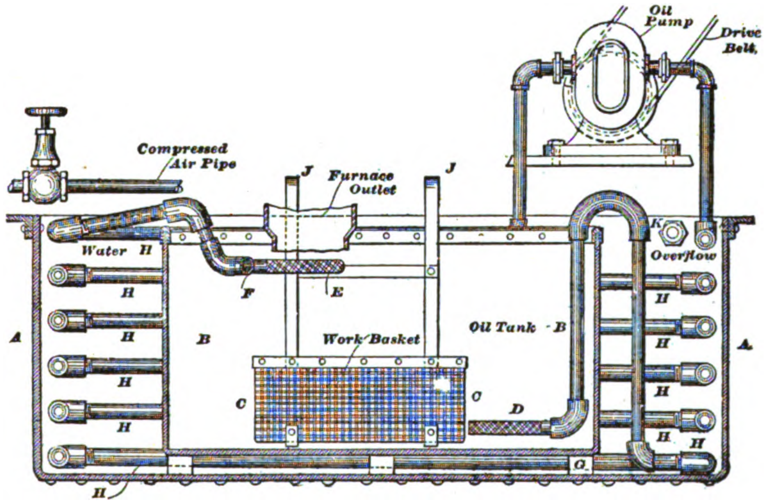


Fig. 136. — Improved Hardening Tank for Automatic Hardening Machines.

the cooled oil. A valve is a compressed air pipe which has an outlet at the bottom of the oil tank is utilized to stir up the oil while the basket is being removed and the hardened work dumped out, thus expediting the cooling of the oil. The furnace outlet is from the muffle of the furnace of the machine shown in Figs. 130 and 131, through which the heated parts pass into the oil. The oil rises to a level with the outlet rim, and thus the heated parts do not encounter an oxidizing atmosphere during the process. The oil pump and its connections with the coil are clearly shown, and requires no description in order to be understood.

Specifications of Cooling Tank

100	feet of	1 -inch pipe.
13	pieces	1 -inch pipe 54 inches long.
12	pieces	1 -inch pipe 32 inches long.
2	pieces	1 -inch pipe 19 inches long.
1	piece	1 -inch pipe 16 inches long.
1	piece	1 -inch pipe 15 inches long.
1	piece	1 -inch pipe 12 inches long.
1	piece	1 -inch pipe 7 inches long.
2	pieces	1 -inch pipe 4 inches long.
1	piece	1 -inch pipe 1½ inches long.
1	piece	1¼-inch pipe 8 inches long.
1	piece	1 inch x 1¼ inch branch pipe.
34	pieces	1 x 1-inch elbows.
2	pieces	½ x ½ x 20-inch flat iron for coil brackets.
5	stay rods	½ inch diameter, iron.
1		1¼ inch flange for drain.

Inner tank, 34 x 19 x 18 inches deep, 14 gage galvanized iron.
Outer tank, 51 x 36½ x 20 inches deep, 14 gage galvanized iron.

Another Oil-hardening Bath and Cooling Tank

Figure 137 illustrated another oil-hardening bath and cooling arrangement, which we designed and which is a slight modification of the one shown in Fig. 132. This was installed in works producing accurately hardened parts in large quantities, and its cost together with the heating furnace that went with it was $500. The engraving is self-explanatory, and no description is necessary.

Automatic Tempering Machine

After the hardening of the parts they were sent to the grinders and ground to exact dimensions. It was then necessary to draw both ends for a distance of about ¾ inch to a blue temper. The old way of doing this work was to hold them, two or three at a time, over a Bunsen burner. This method was slow and also unreliable. Therefore, a small automatic machine was installed that did this work perfectly and rapidly, as a boy could handle the parts. The machine consisted of a bed on four legs, equipped with a horizontal burner about ten inches long, made of 1¼-inch

pipe. At the side of this burner an endless chain passed, being carried by two sprockets placed at opposite ends of the table. The chain was equipped with small sheet metal pockets into which the wedge slides were placed by a boy at one end of the machine. As the chain traveled past the burner the ends of the slides were

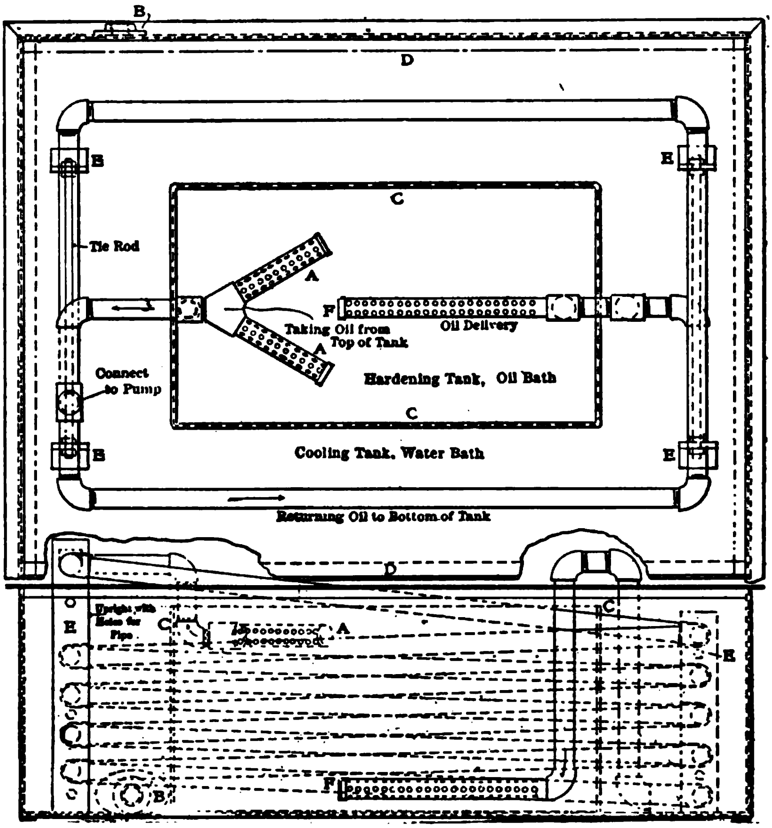


FIG. 137.—Combination Oil-hardening and Water-jacketed Cooling Tank.

tempered to a blue, and upon arriving at the opposite end of the table the work fell out of the pockets and into a box on the floor.

These machines have now been in operation for over a year, and the improved processes have been so successful that a net reduction in the cost of production of wedge slides of almost $4000 per year is being realized. The entire outfit and the labor expended on it did not cost $1000.

SECTION V

PERCENTAGE OF CARBON CRUCIBLE STEEL PARTS AND TOOLS SHOULD CONTAIN, TEMPER COLORS TO WHICH THEY SHOULD BE DRAWN, AND DEGREES OF HEAT FOR GIVING THEM PROPER TEMPERS.

Tool	Carbon, Per Cent.	Color	Deg. of Heat. F.
	A		
Arbors	1.05 to 1.10	Brown yellow	500
Augers	0.70 to 0.80	Light purple	530
Axes	1.15	Dark purple	550
	B		
Ball bearings	1.20	Very light yellow	420
Ball bearing plates	1.15	Very pale yellow	430
Barrels, gun	0.60 to 0.70	Blue	545
Bending and forming dies	0.90 to 1.00	Dark yellow	490
Bits, auger	0.70 to 0.80	Light purple	530
Bits, axe	1.10 to 1.15	Dark purple	550
Bits, channeling machine	1.15	Straw yellow	460
Bits, jointer	1.20	Straw yellow	460
Bits, mining	0.80	Brown yellow	500
Bits, plier	1.00 to 1.10	Dark purple	550
Bits, saw	0.80	Brown yellow	500
Bits, scarf	1.22	Straw yellow	460
Bits, tong	1.15	Brown yellow	500
Bits, well	0.80 to 0.84	Brown yellow	500
Bits, for stone drilling	0.80 to 0.64	Brown yellow	500
Blade, knife	1.15	Straw yellow	460
Blade, pocket	0.90	Brown yellow	500
Blade, reamer	1.20 to 1.22	Straw yellow	460
Bone-cutting tools	0.80 to 1.00	Very pale yellow	430
Boring cutters	1.20 to 1.25	Straw yellow	460
Broaches	1.15 to 1.20	Straw yellow	460

Tool	Carbon, Per Cent.	Color	Deg. of Heat. F.
Burnishers	1.22 to 1.25	Very light yellow	420
Bushing, reamer	0.80	Dark yellow	490
Butt mills for brass	1.20 to 1.25	Very light yellow	420

C

Tool	Carbon, Per Cent.	Color	Deg. of Heat. F.
Cams with sharp corners	1.15	Very dark blue	601
Carver, blades	1.00 to 1.10	Dark yellow	490
Centers, lathe	0.80 to 0.90	Dark yellow	490
Chasers	1.15 to 1.22	Straw yellow	460
Chisels, blacksmiths' cold	0.85	Dark yellow	490
Chisels, brick	0.60 to 0.70	Dark purple	550
Chisels, clay	0.80 to 0.90	Blue	545
Chisels, railroad track	0.85	Dark purple	550
Chisels, stone cutters'	0.80 to 0.85	Dark purple	550
Chisels for cutting files	1.20	Light yellow	440
Chisels for hot work	0.60 to 0.70	Blue	545
Chisels for wood	1.20 to 1.22	Spotted red-brown	510
Chuck jaws	1.20	Dark yellow	490
Circular saws for metal	1.60	Light purple	530
Claw bars	0.65 to 0.75	Light purple	530
Cold chisels for cast iron	1.05	Dark purple	550
Cold chisels for steel	1.20	Light purple	530
Cold chisels for wrought iron	1.10	Light purple	530
Collets	1.20	Dark yellow	490
Coppersmiths' tools	0.95 to 1.05	Light purple	530
Cutters, corn stalk	0.80 to 1.00	Straw yellow	460
Cutters, flue	1.20 to 1.25	Dark yellow	490
Cutters, glass	1.20 to 1.25	Light yellow	440
Cutters, milling	1.20 to 1.25	Straw yellow	460
Cutters, nail	1.20 to 1.25	Dark yellow	490
Cutters, pipe	1.18 to 1.20	Dark yellow	490
Cutters, tong	1.20 to 1.22	Dark yellow	490
Cutting tools for iron	1.05	Light yellow	440

D

Tool	Carbon, Per Cent.	Color	Deg. of Heat. F.
Dental and Surgical instruments	1.22 to 1.25	Light purple	530
Dies, blanking (bottom dies)	0.85 to 0.90	Straw yellow	460
Dies, bolt	0.60 to 0 70	Brown yellow	500
Dies, cartridge shell	1.20 to 1.22	Very light yellow	420
Dies, cutlery	0.60 to 0.85	Brown yellow	500
Dies, drop forging	0.85 to 0.90	Brown yellow	500
Dies, drop forging, for knives	0.68 to 0.78	Dark yellow	490
Dies, envelope	1.15	Straw yellow	460
Dies, for pointing machine	1.15	Very pale yellow	430

Tool	Carbon, Per Cent.	Color	Deg. of Heat. F.
Dies, glove	0.85 to 0.90	Dark purple	550
Dies, hammer	0.67 to 0.78	Very pale yellow	430
Dies, horseshoe (cold punching)	1.20 to 1.22	Straw yellow	460
Dies, large cutting	1.15	Straw yellow	460
Dies, large press forging	1.10	Dark yellow	190
Dies, lever link	0.85 to 0.90	Brown yellow	500
Dies, nail	1.15	Straw yellow	460
Dies, paper cutting	1.15	Pale yellow	430
Dies, pipe	1.15 to 1.22	Straw yellow	460
Dies, rivet	0.60 to 0.70	Dark yellow	550
Dies, silver spoon	0.85 to 0.90	Straw yellow	460
Dies, silversmiths'	1.15	Dark yellow	490
Dies, tong	1.10 to 1.18	Dark yellow	490
Dies, wire drawing	1.20 to 1.22	Straw yellow	460
Drawing mandrels	1.20	Very light yellow	420
Drifts	1.20 to 1.25	Brown yellow	500
Drills, quarry	1.10 to 1.18	Light purple	530
Drills, twist	1.20 to 1.22	Straw yellow	460
Drills for boring shotgun barrels	1.10	Dark yellow	490
Drills for brass	1.22	Straw yellow	460
Drills for glass	1.22 to 1.25	Tinge of yellow	410
Drills for tool steel	1.15 to 1.20	Straw yellow	460
Driver, screw	0.60 to 0.70	Dark purple	550
E			
Edging cutters	1.15	Light purple	530
Embossing dies	1.22	Light yellow	440
F			
Firmer chisels	0.90 to 0.95	Dark purple	550
Flat drills for brass	1.20 to 1.25	Brown yellow	500
Flat drills for steel and iron	1.15	Straw yellow	460
Flatters	0.60 to 0.70	Brown yellow	500
Framing chisels	1.05	Dark purple	500
G			
Gages	1.05 to 1.15	Brown yellow	500
Gimlets	0.85 to 0.95	Dark purple	550
Grips for tube work	0.85 to 0.90	Dark purple	550
H			
Hack saws	1.05	Brown yellow	500
Half-round bits	1.22 to 1.25	Straw yellow	460
Hammer, ball peen	0.80 to 0.85	Straw yellow	460
Hammer, blacksmiths'	0.67 to 0.78	Straw yellow	460

Tool	Carbon, Per Cent.	Color	Deg. of Heat. F.
Hammer, bush	1.25 to 1.30	Brown yellow	500
Hammer, bush for granite	1.15	Brown yellow	500
Hammer, faces	1.05 to 1.10	Very pale yellow	430
Hammer, machinists'	0.90 to 1.00	Very light yellow	420
Hammer, nail machine	1.05 to 1.10	Straw yellow	460
Hammer, peen	1.15	Brown yellow	500
Hammer, pneumatic	0.60 to 0.70	Brown yellow	500
Hammers and drop dies	1.15	Spotted red-brown	510
Hand plane irons	1.10 to 1.20	Brown yellow	500
Hand springs	1.28	Purple blue	535
Hand tools	1.25	Light yellow	440
Hatchets	1.15 to 1.22	Brown yellow	500
Hobs for dies	0.80 to 0.90	Straw yellow	460
I			
Inserted saw teeth	1.25	Straw yellow	460
Ivory cutting tools	1.10	Very pale yellow	430
J			
Jaw, chuck	0.85 to 0.90	Brown yellow	500
Jaw, gripping	0.85 to 0.90	Straw yellow	460
Jaw pieces	0.95 to 1.05	Purple blue	535
Jaw, vise	0.85 to 0.90	Spotted red-brown	510
Jaw, wire puller	1.10 to 1.18	Straw yellow	460
Jaw for pipe machine	1.15	Brown yellow	500
Jaws	0.73 to 0.78	Straw yellow	460
K			
Key for hammer	0.75 to 0.80	Blue	549
Knife, belt	0.80 to 0.85	Spotted red-brown	510
Knife, blade	1.00	Brown yellow	500
Knife, carver	1.00	Brown yellow	500
Knife, corn	0.80 to 1.00	Brown yellow	500
Knife, draw	1.20 to 1.22	Straw yellow	460
Knife, envelope	1.20 to 1.22	Very pale yellow	430
Knife, hog	1.15	Straw yellow	460
Knife, machine	1.20 to 1.22	Brown yellow	500
Knife, paper	1.15	Straw yellow	460
Knife, putty	0.90 to 1.00	Blue	549
Knife, scarfing	0.90 to 0.95	Brown yellow	500
Knife, shear	0.85 to 0.90	Straw yellow	460
Knife, straw cutter	0.80 to 0.90	Brown yellow	500
Knife, whittler	1.15	Brown yellow	500
Knife, wood working	1.15 to 1.20	Straw yellow	460

Tool	Carbon, Per Cent.	Color	Deg. of Heat. F.
L			
Lathe tools for brass	1.15 to 1.20	Very light yellow	420
Leather-cutting dies	1.22 to 1.28	Straw yellow	460
Lining for brick dies	1.20 to 1.25	Straw yellow	460
M			
Mandrels	1.05 to 1.10	Dark yellow	490
Milling cutters	1.20 to 1.25	Straw yellow	460
Milling cutters for brass	1.20 to 1.25	Very light yellow	420
Moulding and planing tools	1.10 to 1.15	Dark purple	550
N			
Needles	1.20 to 1.25	Dark purple	550
P			
Paper cutters	1.25	Very pale yellow	430
Parts subject to shock	1.05 to 1.10	Very dark yellow	505
Penknives	1.18	Straw yellow	460
Percussion tools for metal	0.85 to 0.95	Brown yellow	500
Planer tools for iron	1.05	Straw yellow	460
Planer tools for steel	1.15	Very pale yellow	430
Planer tools for stone	0.70 to 0.80	Brown yellow	500
Planer tools for wood	1.15	Straw yellow	460
Pliers	0.85 to 0.95	Brown yellow	500
Press dies for brass	1.20	Light purple	530
Press dies for cold rolled stock	1.25	Brown yellow	500
Press dies for leather	1.25	Straw yellow	460
Press dies for paper	1.25	Brown yellow	500
Press dies for sheet metal	1.15	Straw yellow	460
Punch, blacksmith	0.80 to 0.85	Brown yellow	500
Punch, cartridge shell	1.20 to 1.22	Straw yellow	460
Punch, file blank	1.20 to 1.22	Blue	549
Punch, hot work	0.85 to 0.90	Brown yellow	500
Punch, oil cloth	0.85 to 0.90	Brown yellow	500
Punch, railroad track	1.85	Blue	549
Punch, skate blade	0.85 to 0.90	Blue	549
Punch, washer	0.80 to 0.88	Blue	549
R			
Reamers, hand, all kinds	1.20 to 1.23	Straw yellow	460
Rock drills	1.10 to 1.18	Straw yellow	460

Tool	Carbon, Per Cent.	Color	Deg. of Heat. F.
S			
Saws, band	0.68 to 0.75	Light yellow	530
Saws, circular	0.80 to 0.90	Straw yellow	460
Saws, cross-cut	0.85 to 1.00	Brown yellow	500
Saws, gang	0.90 to 1.00	Straw yellow	460
Saws, mill	1.25 to 1.30	Spotted red-brown	510
Saws for bone and ivory	1.10	Dark purple	550
Saws for sawing steel	1.60	Light purple	530
Saws for wood	1.15	Dark blue	570
Scarfs	1.20 to 1.25	Brown yellow	500
Scrapers	1.23	Very light yellow	420
Scrapers, tube	1.20 to 1.22	Brown yellow	500
Scrapers, for brass	1.23	Very pale yellow	430
Screw drivers	0.95 to 1.05	Dark purple	550
Screw-cutting dies	1.15 to 1.20	Straw yellow	460
Shear blades	0.90 to 1.10	Dark yellow	490
Shell end mills	1.05 to 1.10	Straw yellow	460
Shell reamers	1.10 to 1.20	Brown yellow	500
Shell thread dies	1.15 to 1.25	Dark yellow	490
Slight turning tools	1.20 to 1.25	Very pale yellow	430
Small milling cutters	1.20 to 1.25	Straw yellow	460
Springs	1.15 to 1.23	Very dark blue	601
Springs	1.18 to 1.25	Dark purple	550
Steel-engraving tools	1.20 to 1.28	Very pale yellow	430
Stone-cutting tools	0.95 to 1.05	Straw yellow	460
T			
Taps and Dies, hand, all kinds	1.20 to 1.25	Straw yellow	460
Taps, nut	1.15	Straw yellow	460
Taps, spindle	1.20 to 1.22	Straw yellow	460
Threading dies for brass	1.18 to 1.20	Light yellow	440
Tools for cutting soft stock	0.80 to 1.00	Very light yellow	420
Tool for reaming inside of guns	1.05 to 1.12	Very pale yellow	430
Tool for turning hard rubber	1.05	Straw yellow	460
Tools for wood to be filed	1.05	Purple blue	535
Tools for wood, not to be filed	1.18	Spotted red-brown	510
Twist drills	1.20	Brown yellow	500

TABLE OF TEMPER COLORS OF STEEL

Very light yellow	420
Faint yellow	430
Straw color	460
Dark straw	470
Dark yellow	490

Brown yellow	500
Spotted red-brown	510
Purple	530
Blue	550
Full blue	560
Polish blue	580
Dark blue	600
Pale blue	610
Blue tinged with green	630
Bright red in dark	725
Red hot in twilight	884
Red visible by day	1077

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